Technical Publication
SA - TP17
August 1981

Proceedings 1980 Southern Nursery Conference

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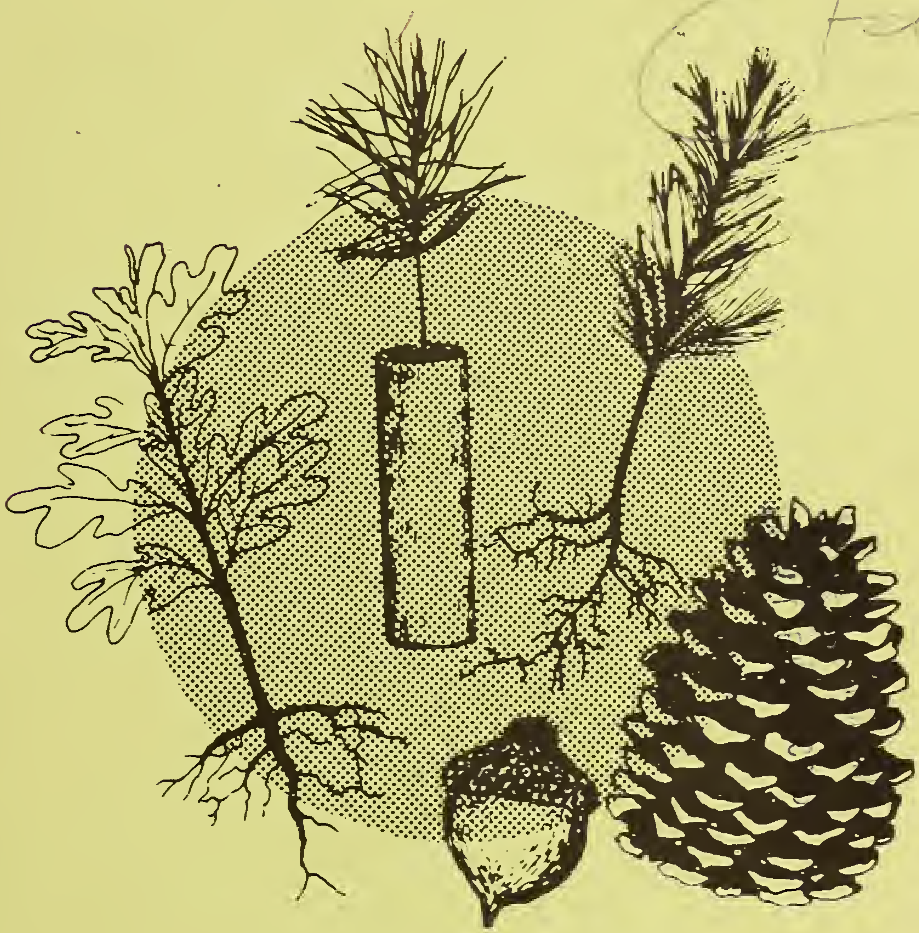

Lake Barkley, Kentucky
September 2-4, 1980

Co-sponsors: Kentucky Division of Forestry
USDA Forest Service - State and Private Forestry
Southeastern Area

Table of Contents

"Compiler's Note"

Our tenth anniversary meeting at Lake Barkley was a resounding success! Thanks to a great deal of hard work and good planning from Dave Fisher, Levada Jackson and many other Kentucky Division of Forestry personnel the entire conference progressed smoothly, and on schedule, from opening remarks to closing ovation. We hope that the ten year tradition will continue as we look forward to 1990!

This proceedings is dedicated to the following retiring nurserymen:

W. M. Drury - Brunswick Pulp Company
Clyde Gehron - Louisiana Forestry Commission
H. E. Hyde - Alabama Forestry Commission
E. C. Jones - Mississippi Forestry Commission
Charles Martin - U.S. Forest Service
Jack Rhody - Kentucky Division of Forestry
Will Schowalter - U.S. Forest Service

Our best wishes for many happy retirement years!!

Clark W. Lantz

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Lake Barkley 1980·"Others"

Lake Barkley 1980·Nurserymen

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245

A DECADE OF PROGRESS [7-3]

100 Robert G. Hitt 1/

Abstract.--The talk traces southern nursery production and tree improvement progress during the 1970's. Planting gradually increased from 875 thousand acres to over 1.3 million acres. Seedling harvesters, improved environmentally acceptable weedicides for use in nursery operations, precision seeders and shrinking nursery budgets have all been a part of the action for the decade. Current seedling production, southwide, is about 50 percent from genetically improved seed -- target 100 percent by the late 80's. A new southwide emphasis on pine reforestation will place great pressure on nursery production facilities during the next decade but southern nurseries and southern nurserymen will meet the challenge!

As I looked at the title for my presentation today, I began to wonder -- is that a question or is it a statement of fact? Well, I decided to make it a question. -----A decade of progress??? Has it really been that???

Including and since your 1970 meeting you have had nine Southern Nurserymen Conferences. Eight hundred and eleven of you attended these meetings and listened to at least 166 different papers on more than 67 different subjects. Five proceedings were published with a total of over 900 pages. What a learned group you are!!!

Ten years ago at this same meeting, at this same place, you talked about and listened to discussions about equipment which included topics on nursery systems, the seedling harvesters, and hydro-mulching. A second topic was nursery management including packaging, stock packing and incentives; another topic dealt with insect and disease control in nurseries and seed orchards, furthermore, other topics included weed control, soil management, seed handling and tree improvement...seven broad topics.

Now gathered ten years later, you have six major subject or topic categories----three old ones and three new ones. While equipment, its development and maintenance, is still a chore and often a problem for all of you, now you have stopped talking about it so much and you are just doing your "thing" with it......packaging, seedling harvesters, hydro-mulchers, precision seeders and on and on. You're moving out-----great!!! That's certainly a step forward!!!

Let's look at the early 70's....seedling harvesters were just coming on scene..on drawing boards and onto nursery beds. Hydro-mulching was relatively new for forest nurseries. Weighing versus counting of seedlings was still in the trial stages at many nurseries around the South.

Bill King was incentive-paying his packers. (He says he still is!)

1/ Staff Director, Special Forestry Services Unit, USDA Forest Service, Southeastern Area, State and Private Forestry, Atlanta, Georgia.

Fusiform rust and black root rot were taking their toll.

Auburn's Mason Carter had a series of herbicide/weedicide tests going in numerous nurseries around the South.

Seed orchards were springing up all over and so were the problems associated with them----graft incompatibilities, wind throw, seed bugs, no pollen, fusiform rust-----. There were others!

How about seedling production and acres planted back then??

Well, back in 1970, collectively you produced about 625 million trees. The trees planted slightly over 875 thousand acres. By 1973 and 1974, the Forestry Incentives Program began to crank up and your seedling production also increased. By 1975, total planting and seeding across the South for all types of ownerships had increased to over 1.27 million acres.

The mid 70's saw great strides in developmental work and widespread use of continually improving models of seedling harvesters.

Auburn University, through the Federal/State Cooperative Weedicide Project, made notable progress in its pilot testing of a wide spectrum of weedicides in your nurseries across the South.

Don Marx and his Research group at Athens, Georgia, began to get excited about "fungi of the roots"---Mycorrhizae. Their work has continued to be of great value in improving not only the quality of the planting stock you men produced, but perhaps even more importantly, the ability of that stock to survive and thrive under good to very adverse site conditions.

On the National scene, the Watergate mess had come and gone---but it was not forgotten. The stock market had run up, down and sideways. Vietnam, for all its cost and losses of lives and other resources, became a National disgrace. On the brighter side, Gerry Ford kept using his head on the golf courses around the country!

But back to the South....new State Foresters were coming on board and new forest industry nurseries began to spring up in various places around the Southern States. Clark Lantz left the academic community to join State and Private Forestry in the mid 70's as our Nursery and Tree Improvement Specialist.

By this time, too, a few of the more experienced nurserymen had retired, changed jobs, gone on to help establish and run industrial nurseries and a few had traveled on to that weedless, greener nursery in the sky.

Now as we move into the last third of the 70's, we see a flurry of activity. Many new faces as well as more nurseries are established. Early in the 70's there were nearly 60 nurseries in the South. By early 1978, there were nearly 70 nurseries---practically---since a number were under development or in various stages of production start up - nine new company nurseries in the last two years.

In 1977-78, you produced a total of about 895 million seedlings which planted about 1.34 million acres.

F.I.P. planting as a part of this had gradually increased from 130 thousand acres to over 192 thousand acres annually. I'm told that last season, the planting probably exceeded 200 thousand acres.

By 1978, seedling harvesters were common place. Seed orchards and improved quality seedling stock production were big on the scene. In the 13 Southeastern States in 1977-78, you produced over 370 million genetically improved seedlings. Now that was 41 percent of the total production!!! I suspect this year your genetically improved seedling production will approach, if not exceed, 50 percent of your production. You are well on your way to 100 percent production of improved stock by the mid to late 80's..Bravo.

Oh yes, I should mention, too, that during the mid 70's, Dr. Steve Boyce and his team at the Southeastern Forest Experiment Station in Asheville began to tell us of the great shortfall in acreage replanted each year to pines here in the South. We were harvesting about 5-6 hundred thousand more acres each year than we were replanting...thus creating a tremendous backlog of acreage in need of replanting. And equally as important, increasing the shortage of certain age classes of growing stock -----tomorrow's harvest, if you will.

In late 1977, Director John Vance of State and Private Forestry, put together a special Task Force to look into the problem and make recommendations. This was done. Work on that problem has continued to date and Bob Lentz, Staff Director in Forestation and Management in State and Private Forestry in Atlanta, will tell you about that in a few minutes .....but one thing for sure coming out of that action was an expressed need for greatly increased production of and increased planting of improved Southern pine seed and seedlings----this is urgent, especially if we are to even come close to meeting the projected wood and fiber needs of the nation by the year 2000 and beyond.

On the problem side, many of your nurseries are now overworked, in need of renovation, need new irrigation systems, more cold storage--- you name it. Some of your nursery acreage, converted years ago to seed orchards, is now needed for seedling production.

On the brighter side, the Herbicide Cooperative is still alive and going strong. In fact, it's about to become two, of sorts, with a companion Cooperative for Silvicultural Herbicides in the offing.

The late 70's also saw Jack May retire from the University of Georgia ---- only from the University of Georgia, however ---- he's still a going strong nursery consultant and a great friend for many of us here today.

Quite a few more of the old gang retired or passed on in the late 70's.

---- And so we have arrived again back at Lake Barkley for another meeting. Some a little grayer, all a little smarter, and not a one any older!!!

Have we made any progress??? Has this been a decade of progress??? Absolutely yessss!!! You collectively produced over 9 billion seedlings which planted over 11.5 million acres here in the South.

---- You are meeting the challenges of nursery management under the new stringent codes for pesticide use.

---- You are dealing effectively with labor shortages and Equal Employment Opportunity constraints.

---- You are carrying on with continually shrinking budgets due to the spiralling inflation.

---- You are moving forward in soil management as you increase your use of testing services and as you put into practice their recommendations.

---- You are practicing insect and disease control measures not only in your nurseries but, as well, in your seed orchard management.

---- You are becoming more and more conscious of the need for cost effective management practices so important in these days of greatly increased costs for labor and supplies.

---- You recognize the importance of seed source and make efforts to seek and use the best possible seed.

---- Ever increasing numbers of you fully utilize the National Tree Seed Laboratory and all of its services. For those who missed that name, it's the new name for your old friend, The Eastern Tree Seed Laboratory---- now it's the National Tree Seed Laboratory at Macon, Georgia.

---- You are still a strong, respected group of men serving a dynamic industry----The Southern Forest Industry----an industry whose products, by the year 2000 and beyond, will furnish over 50 percent of the nation's wood and fiber needs.

---- Your trees of this past decade will be the paper pads, furniture, heat, and houses for the year 2000 and beyond.

Truly, it has been a decade of progress----one you can all be proud of and one whose products will serve our nation for many years to come.

Rest on your laurels, men ----- <u>Never</u>!!! The challenges of tomorrow are great - new issues, new initiatives, new problems, new challenges, new opportunities. Individually and collectively you will meet these issues, initiatives, problems, challenges, and opportunities......and when we reassemble here in 1990 and look back, we will again look back on another <u>great decade of progress</u>!!!

A PINE REFORESTATION ACTION PLAN FOR SOUTHERN FORESTS

ROBERT J. LENTZ [1]/

I compliment you for your accomplishments for the past decade. As Bob Hitt indicated, your success has been through a common sense approach of recognizing the need and going out and getting the job done.

Although you have made significant progress in the 70's, I believe the challenge for the 80's will be even more demanding and crucial to the future of forestry. The Resources Planning Act (RPA) assessment projects rising timber prices which will increase the timber harvest. This means that we can expect a bigger reforestation job.

As Bob mentioned, our track record on regeneration is not the best, for only one half of the acres harvested on pine sites on non-industrial private forest land (NIPF) are adequately regenerated to pine.

RPA emphasizes the importance of these private non-industrial forest lands in the east. Future increases in wood supply must come from NIPF lands. We expect some increases on industry owned lands, however, NIPF lands are really the only land base that we have to increase our timber supplies in the South.

These NIPF lands are the focus of the Pine Reforestation Action Plan for the South. This plan will be distributed within the next few weeks. I won't go into detail here, but will highlight some of the major actions affecting you that are in this plan. A similar effort is under way with forest industry, entitled "Increasing Productivity on Private Non-industrial Forest Lands," published by the National Forest Products Association.

We recognize that reforesting these lands is a challenge and times have changed, for today there is less room for error and inefficency. We are faced with a need for higher production on a smaller land base, with increased emphasis on economics and more accountability. This means, we must seek out and regenerate the most productive sites at the least cost to sustain our wood supplies.

The real challenge in quantified terms is set in the RPA program direction. The RPA Program set the challenge for the 80's with the target of one million acres regenerated annually on NIPF lands in the South before 1990. We also have a target that by 1990 all the seedlings planted in the South will be genetically improved. This effort of one million acres includes efforts on NIPF lands by all segments of the forestry community, for example, State Incentives Programs, industry, State-Federal Cooperative Programs, Soil Conservation Districts, and other forestry program efforts.

This one million acre target will require a mass effort from everyone working in the fields of forestry, no one needs to feel left out. The need is there, demands are identified, and the lands are ready for better management.

[1]/Staff Director, Forestation and Management, USDA Forest Service, programs
Southeastern Area, State and Private Forestry, Atlanta, Georgia.

Research indicates that economic opportunities exist for more intensive management on 168,000,000 acres of commercial timber lands in private ownership in the South. This one million acre annual goal could just be the beginning of a major expansion in the future.

Some skeptics say that the one million acre target cannot be achieved. I believe it will be achieved. In fact, it must be achieved for the economic good of our country. It is attainable; during one year of the soil bank program over one million acres were replanted in the South.

But we know times are different than the soil bank days so we must find other ways to reach non-industrial private forest landowners. We also know that during the height of the soil bank program many state nurseries were established or refurbished.

Once again we are at the threshold of a major reforestation effort that will require expansion of nursery and tree improvement programs. The bait is dangling before us, will we take hold, attack, and lick the reforestation program?

Do we have the courage to take a program that requires an additional 700,000 acres regenerated annually above our current rate? Can we substantiate our needs for reforestation resources and gain public support? Will we act responsibly for the good of forestry, for the economic security of our country by replenishing our renewable resources?

I believe that the forestry community will rise to the occasion and unite to take on this challenge. When the chips are down, we will pull together now as we have in the past, and make significant gains for the forestry community. However, this effort will require strengthening of both government and private sectors striving to achieve a common goal.

Where do we start? The Forest Service in cooperation with State Foresters has prepared an action plan. This plan defines nearly fifty actions to begin this effort. "Beginning" is a key word because the plan should only serve as a tool to initiate the reforestation effort. It needs your ideas, and your actions. Mid-course corrections will be made as needed and I will personally see that these corrections are made as we move through the process. One key action that you need to be aware of in this plan is that the State Foresters will serve to unite forestry interests in individual states through state forestry planning committees or other organizational units set up in the state. This group will identify reforestation problems and needs. This is where you must get involved. You must substantiate the reforestation needs. You must identify how we can share our expertise and resources to get the job done.

Your input is essential. Nursery and tree improvement programs must be recognized as an integral part of the total regeneration picture. This means a look at total wood demands, acres needing regeneration, tree breeding strategies, assistance and cost share programs for seed and seedling production, site preparation, seedling and planting, management and protection of young stands.

245

EXTENDING THE RANGE OF LOBLOLLY PINE IN THE MISSISSIPPI RIVER VALLEY: FACTORS RELATING TO GROWTH AND LONGEVITY [1-5].

100 A. R. Gilmore[1/]

Abstract.--Factors such as soils, snow, ice, cold weather, insects, diseases, rainfall and initial tree spacing that affect growth of loblolly pine north of its natural range in the Mississippi River Valley are discussed. The most important environmental factor to influence growth is rainfall. As rainfall decreases northward in Illinois, site index and wood specific gravity also decrease , which results in a decrease in biomass production. The southwestern Arkansas and Maryland sources of loblolly pine are recommended for planting in Illinois as they are the only strains that have been shown to be resistant to ice and cold weather damage in the area. Planting loblolly north of highway US 40 in Illinois is not recommended.

Additional keywords: Loblolly pine, growth, environmental factors, seed source.

Loblolly pine (*Pinus taeda* L.) has been extensively planted in the Mississippi River Valley during the past 50 years. Some of these plantations are well beyond the northernmost natural range of this species in the Valley, which is northern Mississippi and western Tennessee, about 125 miles south of Paducah, Kentucky.

The areas planted to trees in the Mississippi River Valley that encompass Tennessee, Kentucky, and Illinois have been mostly old fields where the quality of the site has been reduced to the point that native hardwood cannot be successfully grown. Hence it was necessary to find less demanding tree species to reforest these degraded sites. After planting numerous coniferous species over a period of years, foresters now select loblolly pine as the most desirable tree species to plant in the area. In this part of the Valley, loblolly is relatively easy to plant, makes rapid early growth so that weeds and brush are usually not a serious problem, does not have severe insect and disease problems and produces a large mass of stemwood per year.

There are limitations to the northern extension of loblolly's range in the Valley as various environmental and other factors affect its performance. In this paper are discussed the most important factors found to be related to growth and longevity of loblolly pine north of its natural range in the Mississippi Valley.

FACTORS RELATED TO GROWTH

There is a dearth of published reports on growth of loblolly pine in the middle and upper Mississippi Valley. The few reports that are available pertain to plantations growing in Illinois. Therefore, examples and conclusions

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[1/]Professor Forest Soils, University of Illinois at Urbana-Chamapaign. A portion of this research was supported by funds from the Illinois Agricultural Experiment Station, McIntire-Stenis Project 55-328.

in this paper are based mainly on these reports and accepted principles or proven facts.

Soils

Soils influence the growth of loblolly pine in Illinois by regulating the amount of available moisture in the soil during the growing season. When moisture is deficient or excessive, growth slows or ceases. Factors that influence the availability of soil moisture for loblolly pine growth in Illinois are (1) the amount of space occupied by roots above an impervious layer, (2) the water-holding capacity of this space (sand, silt and clay content) and (3) the susceptibility of the soil to water-logging (surface drainage).

Most soils in Illinois where loblolly pine has been planted have a loessal cap with the top soil being a silt loam. Nitrogen is usually the nutrient that is most limiting for tree growth on these areas. A soil test should be made before planting an old field as those areas that have been previously limed might result in reduced height growth for loblolly pine (Gilmore 1975).

Soils in the western Kentucky-Tennessee area are composed of loessal and cherty materials. The latter soils are not as highly productive in the natural state as the loessal ones.

Snow and Ice

Accumulation of snow and ice on limbs and needles of loblolly can result in bent and broken limbs and tops of trees destroyed. Trees from six geographic sources of seed of loblolly pine (Table 1) have been tested in Illinois

Table 1. Survival, Growth And Damage By Snow To Loblolly Pine From Six Regions Of Origin. 1/

Region of Origin	Survival (Percent)	Height (Feet)	Diameter (Inches)	Basal Area (Ft^2/Acre)	Volume (Ft^3/Acre)	Trees Damaged (Percent)
Maryland	57	61	6.6	173	4,418	1.9
Virginia	55	62	6.7	171	4,473	2.7
Arkansas	62	63	6.9	203	5,535	3.7
North Carolina	41	62	7.2	155	4,078	11.3
South Carolina	43	59	7.1	151	3,812	7.4
Mississippi	42	61	7.4	156	4,254	12.4

1/ Percent trees damaged is at age 10 years; all other data are 27 years results.

for 27 years. Results to date indicate that the northerly sources are better adapted to withstand the snow and ice conditions in Illinois than the most

southerly sources (Gilmore and Funk 1977). The southwestern Arkansas source was the least damaged and is the source recommended for planting in Illinois at this time. The second choice is the Maryland source.

Insects and Diseases

Loblolly pine is relatively free from insect problems in Illinois and Kentucky-Tennessee. There are occasional outbreaks of pine sawfly larvae and shoot or tip moth, but damage is not great.

Disease is active in older pine stands. Much of the mortality is attributable to *Fomes annosus*, an indigenous root rot fungus. The incidence of this fungus in Illinois is increasing and may become great enough to make thinning undesirable silviculturally because of the predisposition of the uncut trees to infection.

Climate

The most striking feature of climate in the area is rainfall, which is rather uniformly distributed throughout the year in Illinois. It ranges from about 38 inches per year in central Illinois to 46 inches in the extreme south. Because of high temperatures during the summer months, there is usually a drought period of one to three weeks duration, beginning in the early part of July. This period of moisture deficit coincides with latewood production in loblolly pine for that region. Consequently, latewood percentage is lowered, which results in a lowering of wood specific gravity. As shown later in this paper, under these conditions biomass production is reduced.

Total height of loblolly pine can be shown to be related to rainfall. For example, Gilmore *et al*. (1966) found a high correlation between latitude and site index (height at base age of 40 years) ranging from 46 in Central Illinois to 80 north of the Ohio River near Paducah, Kentucky. This information can be translated to show that the low site index occurs in the area of 38 inches of rainfall with the high site index occurring in the 46 inches rainfall area.

It has been shown that wood specific gravity of loblolly pine gradually decreases from the southern to the northern part of its range in the Mississippi Valley (Gilmore 1967). Also, that wood specific gravity is related to warm season rainfall in Mississippi (Wheeler and Mitchell 1962) and available moisture during the summer in Illinois. This increase or decrease in wood specific gravity is directly related to latewood percentages which is correlated with available moisture during the summer months -- higher the summer rainfall, higher the latewood percentage, and higher the wood specific gravity.

When we think of yield we should be thinking of biomass production. That is, the total volume of wood produced times the weight per volume (wood specific gravity) of that wood. Table 2 illustrates the importance of wood specific gravity and stem wood yield for loblolly pine in the Valley. A comparison of the average wood specific gravities for loblolly pine in Illinois, Kentucky-Tennessee and Mississippi demonstrates that the pulpwood yield per unit volume for the species is considerably lower in Illinois than in Kentucky-Tennessee or Mississippi. The greater wood yield per cord in Mississippi a-

Table 2. Wood Specific Gravity, Percent Latewood And Yield Per Cord Of Loblolly Pine In The Mississippi Valley. 1/

	Illinois		Kentucky-Tenn.		Mississippi
Specific Gravity	.403		.424		.479
Percent Latewood	21		28		----
Lbs/ft^3	25		27		30
Lbs/90 ft^3	2,250		2,430		2,700
Diff. Lbs/cd		180		270	

1/ Median age of 20 years.

mounts to a considerable quantity of pulp for a mill that uses a large volume of wood. Assuming that a cord and a half per acre per year is produced in all areas of the Valley, approximately 7 tons less wood (dry weight base) per acre is produced at pulpwood age (20 years) in Illinois than on a comparable acre in Mississippi and about 3 tons less than in Kentucky-Tennessee. Even if wood is bought by weight, the cost of handling and pulping the wood of lower specific gravity will result in less profit for the pulp company and more than likely a lower price to the grower for stumpage. These computations demonstrate how yields are lowered as loblolly pine is planted outside its natural range in the Valley.

Site Index

There is more stem wood produced at a given age on sites in southern Illinois than in central Illinois. This fact is easy to demonstrate by considering the previous site index figures given for the two areas (80 vs 46 for southern and central Illinois respectively). If these site index figures are equated to the number of cords produced per acre in 25 years we find that for a site index of 80 we will grow approximately 50 cords per acre and for a site index of 46 the production will be approximately 35 cords.

Not only must we look at volume production but also biomass production. Gilmore *et al*. (1966) showed a positive correlation between wood specific gravity and latitude. Their findings equates to a wood specific gravity of approximately .415 in southern Illinois and .390 in central Illinois. When the weight of the two yields (50 and 35 cords) are computed we find that the southern area will yield 21 more tons of dry wood in 25 years than a similar area in central Illinois.

Spacing

One of the most difficult forest management problems to solve is to determine the optimum growing space needed for each age and site so as to obtain

the desired wood products most rapidly. Twenty-five years data shows that for an unthinned loblolly pine plantation growing on a medium quality site in southern Illinois, a spacing of 8 x 8 feet is superior to a 4 x 4, 6 x 6 or 10 x 10 feet spacing (Arnold 1978). This spacing will yield more cubic feet volume and cords than the other spacings. Thirty years data for this unthinned plantation shows that the 8 x 8 feet spacing is still superior to the other spacings, yielding 58 cords as compared to 26, 45, and 56 cords for the 4 x 4, 6 x 6, and 10 x 10 feet spacings respectively. 1/

Initial spacing in a plantation will affect total height of loblolly pine after the crowns close. In the above plantation, total heights of all trees at thirty years averaged 73 feet in the 10 x 10 and 8 x 8 feet spacings, 69 feet in the 6 x 6 spacing and 61 feet in the 4 x 4 spacing. These reduced heights will result in reduced yields.

Yield Comparison

While loblolly pines growth and yield in southern Illinois are encouraging, it is less than that reported in its natural range. For example, in Louisiana, 18-year-old loblolly pine planted at 8 x 8 feet spacing averaged 1.9 cords per acre per year (Hansbrough 1968). In Illinois, the growth at this spacing has been 1.7 cords per acre per year (Gilmore and Gregory 1974). The best yield in the Louisiana plantation was 40 cords per acre in 18 years planted at 10 x 10 feet, whereas in southern Illinois loblolly produced only 26 cords per acre at 10 x 10 feet in 18 years.

FACTORS AFFECTING LONGEVITY

Loblolly pines of southern origin are adapted to longer frost-free seasons and are inherently capable of greater growth than those from more northerly sources. But if loblolly pine grown from southern seed are moved too far north, they may grow too long in the year and be subject to late spring or early autumn frosts or may be so poorly adapted as to suffer cold damage during the dormant season. This condition prevailed in a loblolly seed source study in southern Illinois (Gilmore and Funk 1977). The most southerly sources of loblolly were seriously injured by frost and cold so that survival was less than half of the original stand. The northerly sources such as Maryland and Arkansas were less damaged and survival averaged 60 percent.

There is an axiom in plant ecology that the range of a species is not governed by the average conditions (competition, climatic, etc.) that exist in the area but by the extremes which might occur once in 25 to 100 years. This axiom was substantiated during the late 1970's in central Illinois. A plantation of loblolly pine of Maryland seed source was established in 1948 near Champaign which is about 325 miles north of its natural range (Lorenz and Jokela 1965). The trees made adequate growth during their first 30 years, attaining a height of 56 feet, which is above the average for loblolly through-

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1/ Adapted from file report, "Growth of loblolly pine after 30 years at different initial spacings", by L. E. Arnold, July 18, 1980.

out Illinois for this age. Extreme cold weather occurred during the three winters from December 1976 through February 1979 (Table 3). These extreme low

Table 3. Lowest Monthly Temperatures And Departure From The Mean Minimum For Selected Periods.[1/]

	Lowest Temperature				Departure From Mean			
	76-77	77-78	78-79	79-80	76-77	77-78	78-79	79-80
				Degrees F				
November	9	4	23	20	-7.5	+ 3.2	+ 3.5	+ 0.5
December	-9	- 6	4	3	-9.0	- 3.3	+ 0.8	+ 4.1
January	-8	-13	- 5	-14	-4.0	-15.7	- 9.9	-12.7
February	-2	- 1	- 2	-12	+7.5	+ 0.3	-10.1	-12.2
March	23	- 1	- 1	13	+4.8	- 4.0	- 4.0	- 2.1

[1/] There were 13 days below $0^{\circ}F$ in January 1977, 4 days in December 1977, 6 days in January 1978, 11 days in January 1979, and 9 days in February 1979.

temperatures killed most of the trees and for all practical purposes mortality can be considered 100 percent. This case illustrates the point that extreme care should be taken when extending the range of a tree north of its natural range.

CONCLUSIONS

I have discussed various environmental and stand factors affecting growth and longevity of loblolly pine planted north of its natural range in the Mississippi River Valley. The most important factor, rainfall, not only influences the rate of growth of these trees but also density of the wood. It was shown that as rainfall decreases northward in Illinois, site index and wood specific gravity also decreases which results in a decrease in the amount of biomass.

When selecting a seed source for loblolly pine, insect and disease resistance does not appear to be a factor as loblolly is relatively free from these pests in Illinois. Therefore, the primary factor to be considered is to select a strain of loblolly that is the most resistant to ice and cold weather damage. At present, the seed source recommended for planting in Illinois is the southwestern Arkansas source. The second choice is the Maryland source.

If rotation age is to be 25-30 years and silvicultural thinning is not contemplated, the trees should be planted at a 8 x 8 feet spacing. This spacing will give the greatest yield in cords of any other conventional spacing.

Both Arkansas and Maryland loblolly seed sources are susceptible to extreme cold weather. For this reason, planting loblolly pine north of highway U.S. 40 in Illinois, which passes through St. Louis, Missouri, is not recommended.

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245

LOBLOLLY SEED SOURCE FOR WEST KENTUCKY [E-3]

100 Henry F. Barbour[1/]

Abstract.--Loblolly pine survival and growth in seven provenance test plantings in west Kentucky is reviewed following three cold winters, January 1977 through January 1979. Comparisons among geographic seed sources and half-sib progeny lots are made on the basis of survival and height at ages 4 or 6 in the younger tests, and on volume per unit area at age 8 in the older tests. The best geographic seed source is the Mid-South within 75 miles of the Tennessee state line. Other suitable sources include central Arkansas and the region north of a line from Raleigh, N. C. to Cape Hatteras.

Additional keywords: 2-3 Provenance tests, cold-tolerance, Pinus taeda.

INTRODUCTION

Western Kentucky, between the Mississippi and Tennessee Rivers has no native pines. Shortleaf (*Pinus echinata* Mill.) grows naturally to the northwest in the Missouri Ozarks, and both shortleaf and Virginia pine (*Pinus virginiana* Mill.) are found eastward in Kentucky, but none are naturally available locally in western Kentucky.

Westvaco uses a certain amount of pine at its Wickliffe pulp and paper mill on the Mississippi River near the junction of the Ohio River. Some of the pine should be grown near the mill, and all of that will have to be planted.

Many small plantings of pine have been made in western Kentucky in the past four decades, and the Forest Service has planted pine extensively on the Shawnee National Forest in Southern Illinois. Observations and measurements in these plantations find larger volume in loblolly pine (*Pinus taeda* L.) than in any other species. For example, one small stand in Livingston County, Kentucky had grown 31 cords per acre at age 20. Loblolly pine, then, is the species preferred for pulpwood production, even though in west Kentucky it is 200 miles north of the natural range.

Provenance tests of loblolly pine, notably the Southwide Pine Seed Source Study, have documented the geographic variability of loblolly pine (Wells, 1966). Loblolly from the northern part of the range, from Maryland and west Tennessee, grow best only in their native regions. Seed source zones were delineated within the range, but recommendations could not be made directly for planting sites north of the range.

In southern Illinois, loblolly pine from Maryland, Virginia, and Arkansas was reported in 1952 to have survived better and grown taller by age 10 than

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other more southerly sources (Woerheide, 1959). Maryland loblolly in central Illinois by age 16 was reported to have withstood winter temperatures as low as -15° F. (Lorenz, et al. 1965).

PROVENANCE TESTS

Westvaco has loblolly pine seed orchards for Virginia and for the South Carolina Piedmont. We wanted to know if these could also provide seed for west Kentucky.

As a member company of the North Carolina State University - Industry Cooperative Tree Improvement Program, we had access, on a share alike basis, to selected loblolly pines throughout the range. Access to such a resource was an unprecedented opportunity to define the seed sources for north Mississippi, west Tennessee, and west Kentucky.

From 1971 through 1976, I planted fifteen progeny-provenance tests on ten test sites from north Mississippi to west Kentucky. Seeds were provided by members of the N. C. State University Cooperative and are mostly half-sib lots from select trees in the cooperators' seed orchards. This report reviews seven of the tests at the four sites in west Kentucky; two in Livingston County, one in Hickman County, and one in Calloway County.

All tests survived and grew well with no particularly striking differences among geographic sources until January 1977. That was the initial blast, followed by two more unusually cold winters, which separated the cold hardy sources from the susceptible ones in the most dramatic way.

WEATHER

The weather data from three cities near the test sites, Bardwell, Murray, and Princeton, are averaged for summary and display, (figure 1).

The circles are long term average monthly temperatures. Average maximum and minimum for each month in winter and summer are graphed. The coldest winter temperatures are plotted by a star. January 1977 was exceptionally cold, with an extreme mean low 15 degrees below zero, F. Precipitation was below normal, too. Monthly precipitation is displayed along the base. The lines are long term monthly average.

The winters of 1978 and 1979 both were colder than normal, and that of 1978 quite prolonged. The coldest temperatures were near or slightly below zero. We had 22 days when the temperatures stayed below freezing in 1977, 36 days in 1978, 21 days in 1979, and then only ten days during the normal winter of 1980. Summers were normal and are not considered to have influenced seed sources differentially.

1971 TEST

The 1971 test was started in 1970 in the Tennessee nursery and contained four N. C. Piedmont seed lots and two S. C. Piedmont seed lots, and from other nurseries, pitch x loblolly hybrids and a commercial lot.

WEST KENTUCKY WEATHER

Average of Bardwell, Murray, and Princeton

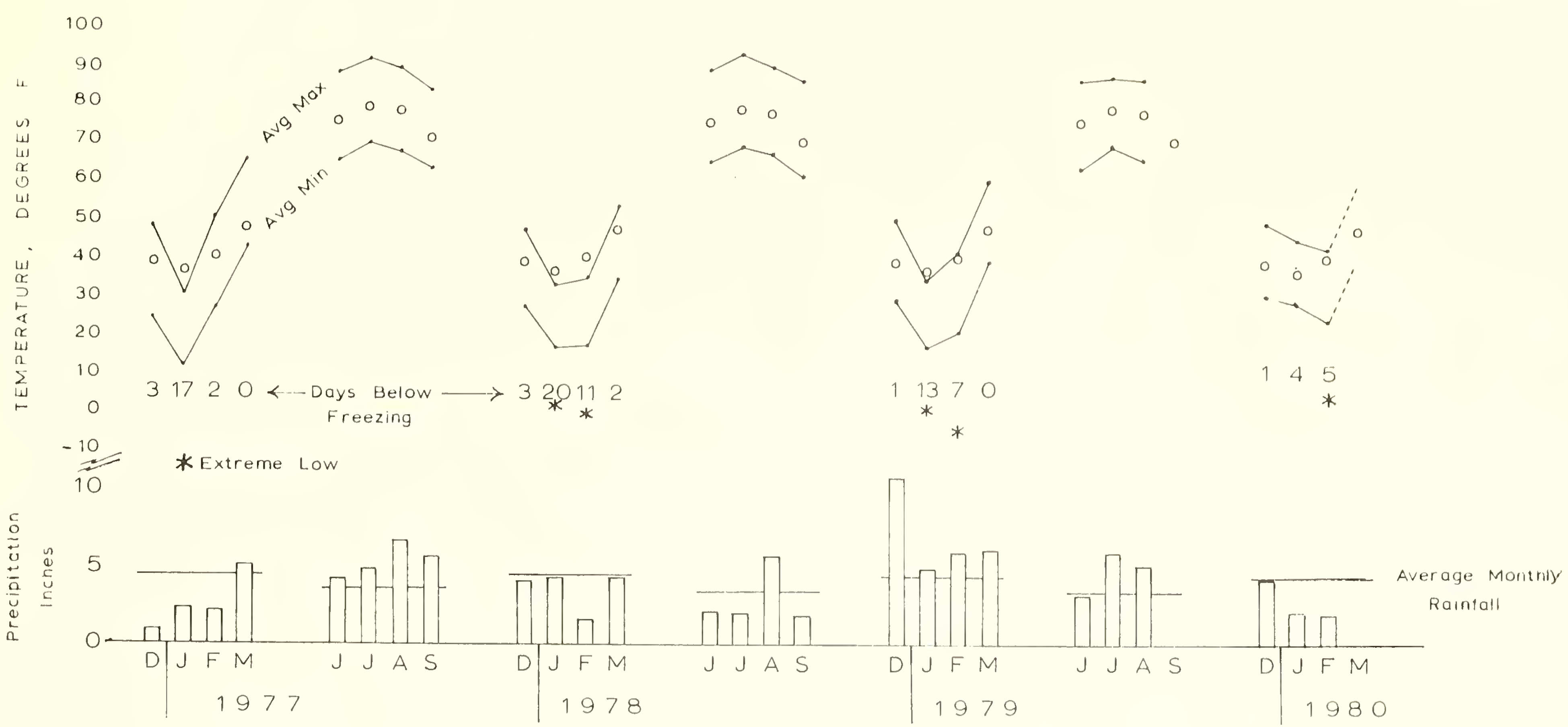

Figure 1

It was planted in March 1971 on a bedded pasture in Livingston Co., Kentucky. Seedling lots were planted in 25-tree blocks at 8 x 8 foot spacing replicated three times.

At age 2, it had emerged above the grass.

At age 4, progeny of N. C. Piedmont trees 6-9 and 8-121 averaged 9 feet tall, the commercial source was shortest at 6.1 feet.

At age 6, in the spring of 1977 following the first abnormally cold winter, the commercial trees were badly browned; only moderate and variable browning occurred on the Piedmont loblolly. The pitch x loblolly hybrids were completely free of damage.

Height and DBH were measured at age 8 in January 1979. Volume has been calculated for total stem cubic feet inside bark (table 1). Seed sources are arrayed by volume per acre as a combined expression of survival and growth. The progeny of some N. C. Piedmont trees are well suited to west Kentucky. Later tests clarify the position of the S. C. Piedmont source.

Table 1.--1971 test, Livingston County, Kentucky

Parent Clone	Geographic Source	Survival	-------Age 8------- Height Ft.	Volume Ft^3/A *
Pitch X Lob	X Maryland Lob.	96%	20.0	530
8-121	N. C. Piedmont	99%	20.2	455
3-35	S. C. Piedmont	97%	18.7	330
6-1	N. C. Piedmont	95%	18.9	325
6-9	N. C. Piedmont	91%	19.4	320
3-4	S. C. Piedmont	81%	17.5	295
6-20	N. C. Piedmont	88%	18.6	275
Commercial	Unknown	39%	13.9	70

*Based on three 25-tree plots at 8' x 8' spacing.

1972 TESTS

The 1972 test seedlings were grown in 1971 at the Kentucky State Nursery as have been nearly all subsequent progeny and provenance tests. I recognize and acknowledge the excellent cooperation of the Kentucky State Nursery in providing well prepared nursery bed space for raising test seedlings in the local climate. Without this valuable cooperation, the scope of these tests would have been much restricted and the early survival and growth would have been altered by distant and various nursery effects.

The 1972 test was planted on an upland cornfield in Livingston, County, Kentucky. Seedling lots were planted in 10-tree rows at 9 x 9 foot spacing replicated three times.

At age 3, it was well above the old field vegetation.

The first cold winter hit the test at age 5 and the effect was obvious by March 1977.

The worst needle browning and subsequent mortality occurred on loblolly from Greenwood County, South Carolina. Moderate and variable browning of all current foliage had developed on trees from Newberry County and others in the South Carolina Piedmont as well as from the North Carolina Piedmont. Seedlings from a Tennessee plantation of unknown original geographic seed source were similarly browned. Arkansas and north Mississippi loblolly were least damaged. Only the needles of the last small flush of the 1976 summer were brown. All earlier foliage remained green.

Survival, height, and volume at age 8 are summarized in table 2. The single-tree source from the northeast corner of Mississippi is the best in survival, growth, and hence volume per acre. This source has already grown a cord per acre per year by age 8 in total stem wood of all trees. Virginia and Arkansas have virtually the same productivity. Trees from the North Carolina Piedmont have good survival and acceptable growth. Trees from the South Carolina Piedmont are inferior in survival and growth.

Table 2.--1972 test, Livingston County, Kentucky

Geographic Source	Number of Parent Clones	Survival	------Age 8------ Height Ft.	Volume Ft^3/A*
Virginia	5	95%	22.4	485
N. C. Piedmont	8	93%	21.6	390
S. C. Piedmont				
Champion & I. P. Co.	9	88%	20.3	345
S. C. Forestry Comm.	7	71%	19.3	225
Arkansas	3	92%	22.4	490
North Mississippi (19-10)	1	97%	23.4	680

*Based on three 10-tree rows per parent clone at 9' x 9' spacing.

On this same cornfield in 1972, I planted some surplus seedlings from the Westvaco South Carolina Coastal seed orchard. At age 5, the severe cold of January 1977 completely devastated the planting. Only a few widely scattered trees are weak survivors.

Surplus seedlings from both North Carolina and South Carolina Coastal seed orchards were planted in Hickman County in 1972. The test site is former agricultural land in the Obion Creek bottom. Following the last crop of soybeans in 1970, the field was bedded and has since grown over with grass and brambles.

Pine survival, height, and volume at age 8 are summarized in table 3. At

age 5, the South Carolina Coastal trees were badly damaged by the first cold winter. The loblolly from Tyrrell County, North Carolina, near the coast and north of Cape Hatteras, retained full crowns of green foliage with only light and irregular needle damage. Their height at age 8 is as good as the 22.4 feet of the Virginia and Arkansas sources in Livingston County and the volume, though not quite up to those two sources, is better than the Piedmont source which produced 390 cubic feet per acre.

Table 3.--1972 test, Hickman County, Kentucky

Geographic Source	Survival	Age 8 Height Ft	Age 8 Volume Ft^3/A*
Tyrrell Co., N. C. (Upper Coastal)	88%	22.5	445
S. C. Coastal	48%	19.9	190

*Based on 9' x 9' spacing for three 60-tree plots of N. C. Loblolly and three 80-tree plots of S. C. Loblolly.

1974 TEST

The 1974 test was also planted in this grassy river bottom field in Hickman County. Its main purpose was to test the first progeny from select pines from the Natchez Trace State Forest, Tennessee, which had been included in the Westvaco seed orchard for north Mississippi, west Tennessee and west Kentucky.

The test included other provenances for comparison since the geographic origin of the Natchez Trace loblolly plantation is not documented.

At age 2, the pines were well up out of the grass. They were three years old in January 1977. Their rapid start was then slowed by the three cold winters.

We delayed height measurements until this past winter at age 6 (table 4). A seed collection from a native stand in Alcorn County, Mississippi just south of the Tennessee state line has the best survival and height in the test. Commercial loblolly of north Mississippi origin, the N. C. Piedmont and upper Coastal sources, and the Natchez Trace pines are all essentially equal. Virginia and Arkansas sources have equally good survival but slightly less height. The inferior position of the S. C. Piedmont is again evident. These data show best that seeds from unselected trees in the correct geographic seed source are better than select tree seed sources from less than the best geographic source.

1975 TEST

The 1975 test is part of an N. C. State University Cooperative test of progeny from selected trees throughout the range. Seedlings were raised at the Kentucky nursery in 1974. In December, good winter color had developed on north Mississippi, north Alabama, northwest Georgia, Virginia and North

Carolina seedlings. Georgia and Louisiana seedlings stayed green all winter.

Table 4.--1974 test, Hickman County, Kentucky

Geographic Source	Parent Clones	Survival	Age 6 Height Ft.
Virginia	4	97%	13.3
N. C. Piedmont	4	97%	14.1
N. C. Upper Coastal	4	90%	13.9
S. C. Piedmont	4	82%	12.6
Arkansas	3	92%	12.9
Natchez Trace St. For., Tenn.	3	93%	13.8
Benton Co., Tenn.	Woods Run	90%	13.3
Alcorn Co., Miss.	Woods Run	100%	14.9
Commercial, N. Miss.	--	90%	13.9

The test site was an old field in Calloway County. Two weeks after I planted this test in May, 1975, some of the Georgia and Louisiana seedlings were dead. The seedlings looked healthy when I planted them, but they had sustained some kind of winter damage which, though not evident to me, prevented them from growing normally after planting.

It was two years old in January 1977. By March, all needles were brown on pines from the South Carolina and Georgia coast and from Louisiana. Needles remained green on pines from Virginia, the North Carolina Piedmont and upper Coast and from the interior Mid-South from north Mississippi across north Alabama to northwest Georgia. Survival and height at age 4 (table 5) show the effect of the winter injury. Survival and growth average 95 percent and 8.8 feet from the sources which remained green. From further south and near the Atlantic and Gulf coasts, survival and growth are less.

Table 5.--1975 test, Calloway County, Kentucky

Geographic Source	Parent Clones	Survival	Age 4 Height Ft.
Virginia	3	93%	8.9
N. C. Coast, Upper	1	97%	9.2
N. C. Piedmont	4	94%	8.6
S. C. Piedmont	2	89%	8.3
N. C. Coast, Lower	2	95%	7.5
S. C. Coast	1	67%	5.5
Georgia Coast	1	43%	5.4
Livingston Parish, La.	--	47%	7.0
Central Alabama	2	92%	7.5
NW Ga., N. Ala., N. Miss.	5	96%	8.8

1976 TEST

The 1976 test, like the 1974, tested a number of trees in the Westvaco seed orchard for this region. Planted in the adjoining field, Calloway County, it was just one year old in January 1977.

By age 4, it had experienced only cold winters. Here also the Mid-South from northwest Georgia to north Mississippi is best (table 6). The Natchez Trace trees are also good. But successful plantations north of the loblolly range are not always a good seed source. The loblolly plantations on the Pennyrile State Forest, Christian County, Kentucky, are a poor risk for western Kentucky.

Table 6.--1976 test, Calloway County, Kentucky

Geographic Source	Number of Parent Clones	Survival	Age 4 Height Ft.
N. C. Piedmont	3	92%	5.8
S. C. Piedmont	5	88%	5.6
NW Ga, N. Ala., N. Miss.	8	93%	6.3
Central Alabama	5	86%	5.7
Natchez Trace St. For., Tenn.	6	89%	6.3
Benton Co., Tenn.	Woods Run	87%	6.1
Pennyrile St. For., Ky.	Woods Run	68%	5.3

By the preponderance of evidence from all these tests, I have outlined the portion of the loblolly range suitable for western Kentucky (figure 2). The interior Mid-South is best from north Mississippi, north Alabama, and northwest Georgia not more than 75 miles south of the Tennessee state line. Next I would use seed from Virginia and North Carolina north of a line from Raleigh to Cape Hatteras. And finally, the northern part of the range in Arkansas is cold hardy enough although the growth rate may be less than from the other two sources. I would not use seed from plantations north of the loblolly range unless their progeny have been tested and proven acceptable.

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LOBLOLLY SEED SOURCES FOR WESTERN KENTUCKY

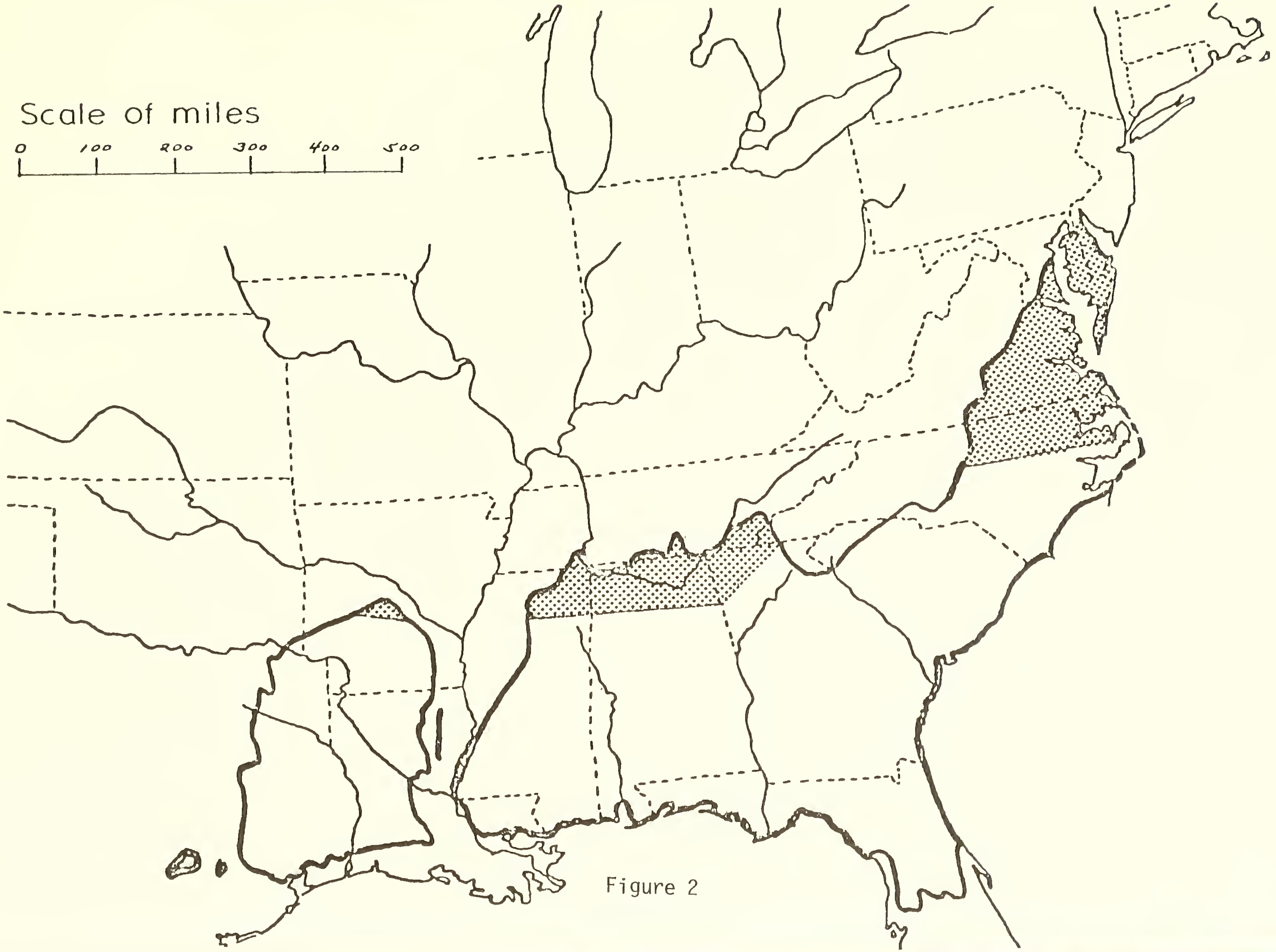

Figure 2

245

PRELIMINARY REPORT ON THE 1979 AMERICAN PULPWOOD ASSOCIATION PINE PLANTATION SURVIVAL AND NURSERY PRACTICES SURVEY

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INTRODUCTION

Pine plantation survival became a concern of many industrial foresters during the 1970's. Concerns were voiced about weather, quality control at the nurseries, changing plantation establishment practices, and type of planting. In response to these concerns, members of the Forest Management Committees of the Southeastern Technical Division (SETD) and Southwestern Technical Division (SWTD) of the American Pulpwood Association (APA) developed a comprehensive survey form to identify problems or potential problems in pine plantation survival. The survey form reported on pine plantation establishment practices and nursery practices for the time period of 1960 through 1979. The time period was broken into four reporting units: 1960-64, 1965-69, 1970-74, and 1975-79. Thus, respondents provided average replies based on five year experience periods. Responses were received from 30 individual firms representing 53 reporting units. Additionally, 26 state nurseries in the South completed a survey form on nursery management practices.

NURSERY MANAGEMENT PRACTICES

State nurseries produced 50% or more of the seedlings planted during the 1960-79 reporting period. Use of industry produced seedlings, however, increased during this period. The rise in industrial nurseries apparently was to take advantage of tree improvement programs and to provide more quality control in seedling production. This section is based on 26 state nursery replies and 17 industrial nursery replies.

Differences in the organizational structure of public and private forest nurseries appear to influence the quality of tree seedlings produced. For example, state nurseries are subject to stringent budgetary limitations with little or no new capital funds available for expansion or improved technology. The state nurseries are confronted with maintaining high production in face of a declining real budget. Industrial nurseries appear to be better funded for the task at hand and are more flexible in adapting new technology. As a result there are differences in the quality of seedlings produced, which may affect plantation yields.

Seedling size. Tree seedlings packaged for planting were consistently smaller in size when shipped from state nurseries as compared with industrial nurseries. The minimum root collar diameter accepted by the industrial nurseries exceeded the state nursery minimum by 29 percent.

State nursery seedlings were taller than industry seedlings at minimum top heights. However, industry seedlings appeared to be more stocky as indicated by their larger root collar diameters (Table 1).

Table 1. Average physical characteristics of seedlings planted in the field (all values in inches).

Seedling Characteristic	Nursery			
	State		Industry	
	Min.	Max.	Min.	Max.
Root collar diameter	0.12	0.22	0.17	0.42
Top height	7.2	15.2	6.7	14.5
Root length	4.7	8.7	7.2	12.8

Forest industry nurseries strive for a seedbed density of 20 to 28 seedlings per square foot. State nursery seedbed densities appear to range from 30 to 40 seedlings per square foot or from 2 to 20 seedlings more per square foot than found at forest industry nurseries. The net result, of course, is a smaller seedling in the state nurseries which requires grading to meet standards. Eighteen state nurseries reported some level of seedling grading while only three forest industry nurseries reported seedling grading.

Shoot/root ratios based on top height and root length highlight the differences in seedling size by nursery. Industry nurseries minimum seedling size ratio was 0.93 while state nursery minimum seedling size ratio is 1.53. At the maximum size, the shoot/root ratios are 1.13 for industry nurseries and 1.75 for state nurseries. At the extremes industry seedlings show better balance in top height and root length. State nursery seedlings have 53 to 75% more top than root.

Cultural practices. Weed control in the seedbed was achieved by fumigation, mechanical, hand, and chemical methods. Use of fumigation and mechanical weeding was similar for industry and state nurseries. Forest industry nurseries used nearly 50% less hand weeding and 7% more

chemical weed control than state nurseries.

Fertilization practices were nearly the same for both industry and state nurseries. About 33% applied some fertilizer throughout the irrigation system and 67% used a top dressing treatment.

Seedling lifting, packaging, and storage. State nurseries reported a 33% higher use of hand lifting and a decreased use of mechanical lifting. Packaging and root protection measures were similar for the two groups. Both normally shipped seedlings in bales. Forest industry reported using more kraft paper packaging than the state nurseries. Root protection was achieved primarily through the use of moss in packaging, although both groups reported some use of clay coatings. Cold storage use has increased for both groups over the reporting period. Nearly equal availability of cold storage facilities at the nurseries was reported by both groups.

Rotation sequence. State nurseries are forced to use the same area for seedling production more frequently than are industry nurseries. Forest industry nurseries approach a rotation of one year in and one year out of production while state nurseries have two or more years of production before lying fallow.

PINE PLANTATION SURVIVAL

In the initial time period (1960-64), 38 industrial respondents reported an average annual planting effort of 6,900 acres. Average survival for the period was 82%. The number of respondents increased to 52 in the last time period (1975-79), and the average planting effort increased to 12,022 acres annually. Survival decreased in the period to a low of 73%. The total acres planted annually increased from 233,495

acres in the first reporting period to 547,122 acres in the last reporting period. Survival was similar for the first three reporting periods, but declined significantly in the last reporting period.

Several major changes occurred in the planting effort during this period. There was a change in species preference, planting method, structure of planting crews, and the kind of lands planted.

Species planted. For the 1960-64 period, slash pine was reported as the first preference by 41% of the respondents and loblolly pine, 52%. Longleaf, sand, and virginia pines made up the remaining 7%.

In the last reporting period, slash pine decreased to only 18% and loblolly pine increased to 79%. Miscellaneous southern pines made up the remaining 3%.

In the last reporting period, 48% of the loblolly pine and 58% of the slash pine planted were genetically improved stock. Only 1.5% of the loblolly pine and 2.7% of the slash pine was from genetically improved stock in the 1960-64 period.

Planting method. Machine planting dominated in the first reporting period (54% of total planting). Hand planting was next at 39%, and machine planting behind a V-blade was at 7%. In the last period, hand planting dominated at 44%. Machine planting was next at 33%, and machine planting behind a V-blade increased to 23%. The change in planting method indicates a change to more difficult planting areas.

Planting crews. In the first reporting period 7 of 10 planting crews were company crews. As the planting programs expanded, the company crews fell to only 3.8 of 10. Contract planting crews have been responsible for more than 50% of the planting programs since 1970. In

the last time period, survival was reported at 77% for company crews and 70% for contractor crews.

Land forms planted. Plantings on abandoned agricultural lands declined considerably over the reporting period. Most of the effort was on cut-over forest land. Major increases in plantation establishment occurred in the upper coastal plain. Here planting increased from 60,700 acres in the first reporting period to 218,850 acres in the last period. Planting of wet sites tripled from 42,000 acres to 125,800 acres. Planting of mountain and droughty sites increased from 7,000 acres to 16,400 acres.

SUMMARY

State nurseries and forest industry nurseries have a common goal to provide quality planting stock. The production process in the industry nursery is capital intensive and less dependent upon low cost labor. State nurseries are restricted by inflation depleted budgets that limit adoption of new technology and force them to maintain labor intensive management practices. Similarly most state nurseries are old and the soils are used repeatedly for seedling crops with limited fallowing. Industry nurseries are new and often managed with alternating cover crops. Demands for seedlings are also greater in state nurseries, thus emphasis is of necessity given more to production than quality. The survey did not provide an assessment of seedling quality upon survival and early growth, but other research relates increased survival and early growth with better quality seedlings.

What is the best philosophy for nursery management in the next 20 years? Seedlings grown and planted during this interval will largely determine southern timber supplies during the period of 2010-2030.

Should public nurseries limit total production to increase average seedling size? Currently 18 state nurseries are still grading seedlings. This grading activity could be minimized by reducing density and growing larger or better quality seedlings. In the entire reforestation process, the individual seedling is one of the least expensive yet most critical items in the process. Also, should nursery managers produce seedlings specifically for each land form area, planting method, and site preparation technique? There is increasing evidence that seedling traits should be developed for site specific conditions.

Pine plantation survival decreased over the reporting period while total annual planting area nearly doubled. Do planting sites need more careful preplanting analysis? The planting areas are not uniform planting sites, and the "average" condition on a 200 acre planting block will mask important changes at the extremes. How specific do the planting recommendations including site preparation need to be?

Industrial forest managers must carefully review the use of contract planting crews. The current mechanism of pricing work for contract crews does not provide an incentive for quality work in tree planting. If contract crews worked under a quality performance based contract, the problem could be minimized.

Accomplishing the required forest planting job over the next 20 years will require increased production of high quality seedlings from state and industry nurseries. The tree planting work in the field must be designed for specific sites, planting techniques, and site preparation treatemnts. Least cost planting may not optimize long term benefits from plantation establishment and management.

A Progress Report: Plantation Survival of Nursery Grown Seedlings in Georgia

by

S. J. Rowan [1/]

Abstract.--Preliminary information from a study of tree survival in plantations in Georgia indicates very little seedling mortality attributable to nursery source, method of lifting, date of planting, or method of transportation. Poor handling and poor planting techniques by landowners or planting contractors appear to be the primary causes of seedling mortality.

Because landowners across Georgia have complained that seedlings purchased from Georgia Forestry Commission nurseries were of inferior quality and died at higher rates than those purchased from other sources, a study was begun this past year (1979). The study was divided into three phases. The first phase was designed to determine if substantial numbers of seedlings purchased from Georgia Forestry Commission nurseries died when processed and planted by the average landowner. From each county in the State one landowner who had ordered one thousand or more slash or loblolly pine seedlings was randomly selected. In each landowner's plantation, 10 plots of 100 trees each were established to measure survival. In this manner sur-

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vival was measured for one plantation in each of 140 of Georgia's 159 counties.

The second phase of the study attempted to determine if method of lifting, transportation to the landowner, or treatment of seedlings by the landowner caused substantial numbers of seedlings to die. In this phase six landowners were randomly selected and permission was obtained to make an experimental planting on their land. We supplied and planted 400 trees for each owner at the spacing planned for the remainder of the plantation. A day or two before the landowner was scheduled to receive his order, the bundle of seedlings stored for the longest time was selected from the packing sheds of one of the two Georgia Forestry Commission nurseries. From that bag plantable trees were removed, tied, labeled and packed into another bag. Another group of seedlings was lifted on the same day with "tender loving care" (TLC) to preserve the maximum number of feeder roots. These seedlings were placed in bags and sealed. Half of the TLC lifted and half of the regular-lifted seedlings were refrigerated for the 3 to 4 days prior to planting. The other half were stored and transported to the planting site in the standard manner by the Georgia Forestry Commission. Thus, there were two methods of shipment and two methods of lifting for a total of four treatment combinations. Each combination was replicated four times in 25-tree-plots. We planted all 400 seedlings by hand with great care. Rate of survival of our seedlings was compared to that of seedlings planted by the landowner to see if handling after receipt of seedlings by the landowner and care in planting was influencing survival.

In phase three of the study the merits of the lifting method used at each of the eight forest tree nurseries in Georgia were compared, along with the relative quality of seedlings from these nurseries. Both regularly and TLC lifted seedlings were collected from the eight nurseries in Georgia in January, February, and March of 1980 and outplanted by machine on three sites. Four 25 tree replicates were outplanted on each site and date for each nursery source and lifting method.

Preliminary results indicate very little mortality that can be attributed to method of lifting, nursery source, date of planting, or method of transportation. The handling of seedlings by the landowner appears to be the primary cause of mortality, and early indications are that poor planting techniques are the real cause of mortality.

245

A COMPARATIVE EVALUATION OF SEEDLING QUALITY IN COMMERCIAL FOREST NURSERIES IN FLORIDA

100 E. L. Barnard, C. A. Hollis, and W. L. Pritchett[1]

Abstract.--A variety of morphological and physiological parameters are being evaluated on sample slash pine seedlings from five commercial forest nurseries in Florida. Seedbed soil characteristics and nursery cultural/handling practices are also being considered in an effort to identify the cause(s) of "unexplained" outplant failures. Under some conditions, reduced survival can be attributed to root loss and/or damage resulting from machine lifting of seedlings. Also, seedling root starch reserves have, to date, exhibited a consistent relationship to first-year field survival of outplanted nursery stock. Methodology employed and the significance of preliminary results are discussed.

Additional key words: slash pine, *Pinus elliottii*, carbohydrates, root starch, seedling survival.

In recent years, foresters in Florida have been plagued by repeated and sometimes extensive regeneration "failures"; i.e., inadequate field performance (survival and growth) of bare-root nursery stock. Through 1976 a significant component of these failures could be attributed to damage sustained by seedling root systems as a result of infection by *Macrophomina phaseolina* (Tassi) Goid. (*Sclerotium bataticola* Taub.), the charcoal root rot fungus (Barnard 1979, Hodges 1962, Seymour 1969, and Seymour and Cordell 1979). More recently, however, seedbed fumigations with appropriate formulations and rates of methyl bromide and chloropicrin have held charcoal root rot infections to a minimum in Florida tree nurseries, and many outplant failures have been relegated to the "unexplained".

In 1978, we initiated a cooperative study in an attempt to identify the major cause or causes of "unexplained" outplant failures. In this paper, we present our approach to the problem, and some of our preliminary results.

METHODS

Sampling: 1978-79 Lifting Season. In the first year of our study we designed our work to evaluate seedling outplant performance as related to

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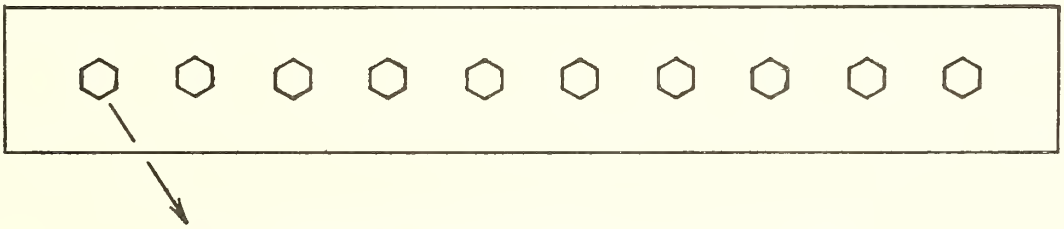
a) seedbed soil fertility, b) seedling morphology, c) seedling physiology, and d) methods of seedling lifting/handling. Sample seedlings (1-0 slash pine = Pinus elliottii Engelm.) were collected systematically from a representative seedbed in each of four commercial forest nurseries in Florida. Sampling was conducted twice; for logistical reasons from one seedbed in early December 1978 ("early-season") and from another seedbed in early February 1979 ("late-season"). Three primary lifting/handling treatments were identified; i.e., I - "hand lifted" by investigators, II - "machine lifted", seedlings taken from the lifting machine in the field, and III - "end-line packed", seedlings machine lifted, transported to packing shed, sorted or weighed according to routine procedures of the individual cooperating nurseries, and sampled just prior to placing bags or bales in cold storage. (Two nurseries bagged seedlings on their lifting machines in the field. Treatment III seedlings in such cases were obtained by opening bags after transport from the field, just prior to cold storage.) Twenty sample seedlings were taken from the middle four rows of each selected seedbed at each of ten locations throughout the length of the seedbed and distributed according to the schematic shown in Figure 1. All sample seedlings were immediately placed in appropriately labelled plastic bags with small amounts of moist pulp fiber mulch and transported on ice in insulated coolers to their respective destinations (i.e., lab, field, etc.).

SAMPLE SEEDBED



20-25 Seedlings from each of 10 locations*

5-10 Seedlings -- outplanted
5 Seedlings -- morphological & nutrient analyses
5 Seedlings -- carbohydrate analyses
5 Seedlings -- mycorrhizae & disease assessment

*Soil sample collected from rhizosphere soil at each location and composited for seedbed soil analysis.

Fig. 1. Schematic representation of seedling sampling and sample distribution systems employed.

Sampling: 1979-80 Lifting Season. In year two of our study we decided to concentrate efforts on evaluation of the seedlings per se as compared to lifting/handling variables. This decision was based largely on preliminary

results from our first year's work. Accordingly, only hand lifted seedlings were evaluated. As in year one, tests were again designed to examine relationships between outplant performance of early- and late-season seedlings and a) seedbed soil fertility, b) seedling morphology, and c) seedling physiology. Seedlings were sampled from each of five commercial forest nurseries during the second year. Sampling and sample handling was conducted as described above, except that this time three seedbeds were sampled in each nursery and samples were taken from the same seedbeds on both the early- and late-season sampling dates.

Seedling and seedbed soil analyses. The following factors were targeted for evaluation and are currently under investigation in our study:

1) seedling weight (green and dry),
2) seedling stem diameters,
3) top to root ratios (green and dry weight bases),
4) disease influences,
5) seedling mineral status,
6) seedling carbohydrate status,
7) seedbed soil nutrient levels,
8) seedbed soil pH,
9) root system mycorrhizae
10) nursery cultural practices.

Establishment of Test Plantings. Experimental plots were established with seedlings representing each specified treatment, nursery, sampling date, and/or seedbed. All seedlings were hand planted within 24 hours following lifting on prepared (chopped-burned-bedded) sites located on well-drained sandy soils (site index = 70+) in central Florida.

In the first year of our study, a randomized complete block design was employed. Four 25-tree square plots were established for each treatment (I, II, III) from each of the four nurseries and each of the two sampling dates. Logistical constraints necessitated a reduction in replication of field plots during our second year's work. Accordingly, we established two randomly located 25-tree square plots with seedlings from each of the three seedbeds from each of the five cooperating nurseries and both early- and late-season sampling dates (thus: 6 plots per nursery; 2 each from each of three seedbeds - repeated in early- and late-season). In all, a total of 156 test plots (3900 seedlings) were established over the two-year period. Survival data were collected at the end of the first growing season (year two data not yet finalized) and growth measurements are being taken annually for a period of three years.

RESULTS AND DISCUSSION

Not all analyses are complete at this time, nor have thorough statistical analyses been conducted. As a result, we are reporting preliminary observations and relationships which are readily apparent. We anticipate a formal and more complete report following the termination of our study.

I. Performance Related to Lifting/Handling Methods. With only one exception, seedlings lifted by hand survived better than those lifted by machine (Table 1). The greatest differences in survival between hand and

Table 1. Survival (%)[a] of hand and machine lifted 1-0 slash pine nursery stock at the end of the first growing season following outplanting in central Florida.

Nursery	Treatment[b]	Date Seedlings Lifted & Outplanted	
		December '78	February '79
A	I-Hand lifted	88	85
	II-Machine	71	34
	III-"End-Line"	68	51
B	I-Hand lifted	52	73
	II-Machine	45	53
	III-"End-Line"	31	58
C	I-Hand lifted	91	82
	II-Machine	83	59
	III-"End-Line"	75	64
D	I-Hand lifted	73	32
	II-Machine	71	42
	III-"End-Line"	62	64

[a]Figures represent means of four replicate 25-tree plots.

[b]Method of seedling lifting/handling at the nurseries.

machine lifted seedlings, not unexpectedly, were recorded for nursery "A". Nursery "A" is located on relatively fine textured soil with a high component of clay, whereas nurseries "B", "C", and "D" are located on predominantly sandy soils, typical of central Florida. Why machine lifted seedlings from nursery "D" survived better than hand lifted seedlings (February sample) is unknown. However, two possibilities should be kept in mind: a) experimental error, and b) nursery "D" employs a slightly different type of mechanical lifter than the other three nurseries. In general, our data reflecting detrimental effects of machine lifting agree with data now being accumulated by C. E. Cordell (personal communication). We attribute this phenomenon to root loss and/or damage sustained by seedlings during the lifting process, and our data suggest that this problem is potentially worse in heavier soils. It must be pointed out, however, that the degree of root loss/damage will vary not only with soil conditions, but with lifter type and care used in its operation as well. Also, survival losses may be greater or less than those we observed, depending upon such factors as subsequent handling of seedlings, outplant site conditions, and weather patterns. The bottom line might simply be stated thus: "It will do you no good to grow a quality seedling if you beat it to death in lifting and handling" (ref. Table 1: Nursery "A" - February sample).

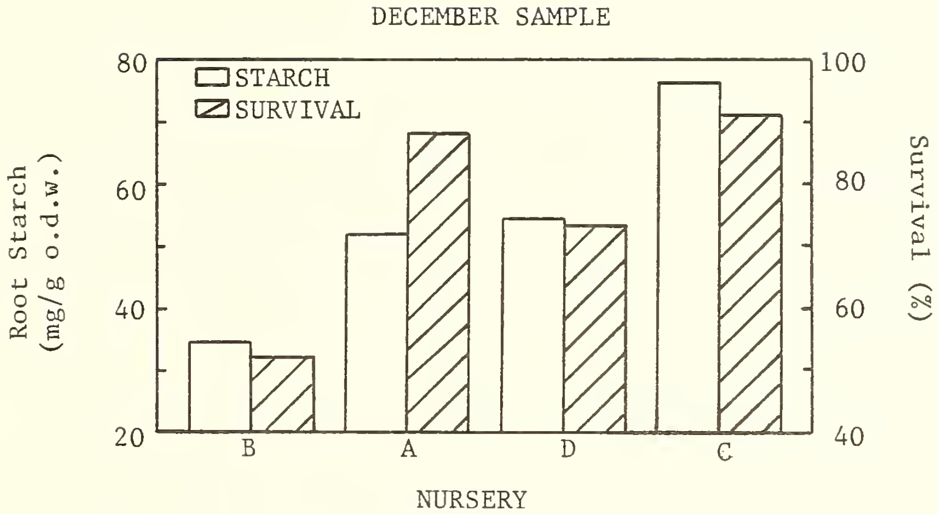
II. Performance Related to Other Factors. Noteworthy differences between individual cooperating nurseries, sampling dates, and/or seedbeds included variations in seedbed soil pH and nutrient levels, seedling size

and/or top to root ratios, seedling nutrient status (inorganic), and seedling carbohydrate status (especially root starch). For example, seedbed soil pH values ranged from ca. 5.1 to 6.2, seedling top to root ratios (biomass - oven dry weight basis) varied from a low of 2.8 to a high of 7.5, stem diameters ranged from 3.6 mm to 5.7 mm, and root starch content varied from ca. 34 mg/g root tissue (o.d.wt.) to 145 mg/g. Seedbed soils as well as seedling tissues showed considerable variation in the amounts of inorganic nutrients present; particularly soil P, Mg, K, and tissue Ca and Mg. In many cases, these differences could be related to nursery cultural practices; e.g., greater seedbed densities usually resulted in smaller stem diameters, mineral nutrient analyses reflected fertilization programs, etc. Not surprisingly, seasonal trends were evident in many measurements, with late season samples having larger stem diameters, lower top to root ratios, and higher levels of root starch. Finally, both qualitative and quantitative differences in mycorrhizae were evident between individual nurseries. While Thelephora terrestris Ehrh. ex Fr. and Rhizopogon nigrescens Coker and Couch were the predominant fungal symbionts in most cases, a major component of the mycorrhizal symbioses in one of the cooperating nurseries was a result of natural colonization by Pisolithus tinctorius Coker and Couch. In no case were diseases (e.g., fusiform rust, root disease, etc.) considered a significant factor in our study.

To date, we have been unable to consistently relate field performance (survival only - growth data incomplete at present) of test seedlings to any of the observed morphological or physiological differences cited above with one apparent exception. While in certain cases outplant survival appeared related to stem diameters and/or top to root ratios, etc., root system starch content has shown the best and most consistent relationship to survival among all factors under consideration. In the first year of our study, two sets of sample seedlings performed miserably in the field relative to their peers. In both cases these seedlings contained significantly less root starch (per gram of dry weight) than did the "relatively good performers" collected on the same sample dates (Fig. 2). Although we have not tabulated all data for our second year's work as yet, there are substantive indications that this root starch - survival relationship is holding up.

III. Significance of Root Starch - Survival Relationships. Wakeley (1954) recognized the "unreliability" of morphological grades as measures of seedling quality (i.e., the ability of seedlings to survive and grow). He pointed out that "morphological grades and physiological qualities may or may not coincide" and stated that "physiological qualities of seedlings can overbalance the effects of their morphological grades upon survival and growth." Stone and his colleagues (Stone 1955, Stone and Schubert 1959, Stone et al. 1963) also recognized these phenomena and proposed methods other than morphological grades for assessing the fitness of seedlings for withstanding the trauma of lifting and outplanting. They proposed "root regenerating potential" (i.e., the ability of seedlings to generate new roots following lifting and outplanting) as a key measure of such "fitness" or "physiological quality".

We believe that root starch reserves may be a valid (and hopefully usable) parameter for assessing the physiological readiness of seedlings for withstanding "transplant shock". When lifted as bare-root stock, seedlings inevitably sustain some degree of root loss or damage. In order to survive



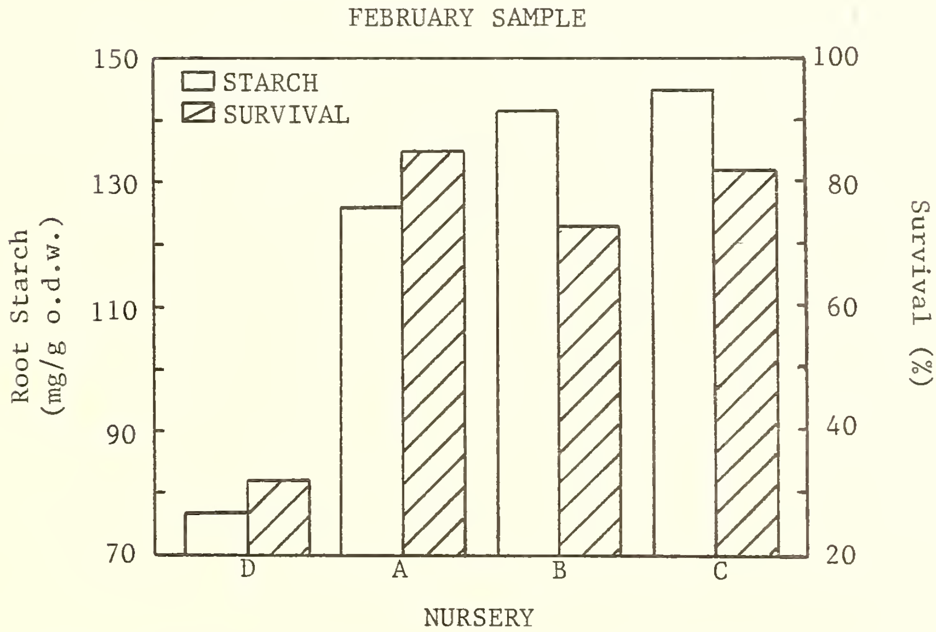


Fig. 2. Relationships between root starch (mg/g o.d.wt. of root tissue) and first year outplant survival of hand lifted 1-0 slash pine nursery stock in Florida. (Root starch content determined at the time sample seedlings were lifted from their respective nurseries' seedbeds.)

following outplanting, especially through periods of drought, etc., it is important that seedlings be capable of rapidly replacing lost roots and establishing adequate contact with their new soil environment by generating new roots. By and large this ability to regenerate roots (i.e., "root regenerating potential" *sensu* Stone *et al*.) is a function of reserve carbohydrates, particularly starch (Farmer 1978, Kozlowski 1971, Kramer and Kozlowski 1960, Larson 1975, Smith 1962, Wakeley 1954) which are accumulated in the seedlings during the growing season.

Assuming that reserve root starch does represent a meaningful measure of "seedling quality", there are several critical needs on which the successful use of this parameter depends. First, "optimum" or "adequate" starch reserve levels must be defined. These are apt to vary with tree species, season of lifting, and post outplant conditions (site, weather extremes, etc.). Secondly, a rapid and reliable method of determining whether or not seedlings have acquired sufficient levels of reserve starch is a must; such a method should be adaptable to field use. And thirdly, the effects of cultural practices (irrigation, fertilization, seedbed density, etc.) and climatic factors on starch metabolism must be determined so that nurserymen can employ management practices which encourage the synthesis and accumulation of this reserve carbohydrate. These and other factors related to "seedling quality" are currently under investigation at the University of Florida.

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295

LIFTING DATE AND STORAGE AFFECT ROOT REGENERATION POTENTIAL OF BLACK WALNUT SEEDLINGS [1-5].

100 W. J. Rietveld and Robert D. Williams[1/]

Abstract.--Seedlings lifted too early in the fall and stored over winter showed low vigor in root regeneration potential (RRP) tests in the spring. Seedlings lifted when dormant stored well and had acceptable RRP, if chilled completely. Highest RRP occurred in seedlings lifted just before bud-swell in early spring. Seedlings should be lifted and stored about 1 month after leaf fall for early-spring planting and just before bud-swell for late-spring planting.

Additional keywords: Physiological quality, chilling, *Juglans nigra*.

Lifting hardwood nursery stock in the fall rather than in spring has become more common because of such seasonal advantages as: better soil conditions, lighter workloads, more available labor, earlier confirmation of stock availability, and prompter delivery of stock to planting sites in the spring.

Black walnut (*Juglans nigra* L.) is one of the first species to be lifted in the fall, because leaf fall occurs early and seedlings seem to be dormant. However, leaf fall only indicates that dormancy has begun; it does not indicate when seedlings should be lifted. Lifting and storing guidelines for black walnut need to be developed based on convenient criteria for identifying seedling readiness.

To learn more about the effects of lifting date and storage, we conducted root regeneration potential (RRP) tests on black walnut seedlings. RRP, a measure of the seedling's capacity to promptly initiate and elongate new roots when planted in a favorable environment, is correlated with field survival (Stone and Schubert 1959, Stone and Jenkinson 1971). Effective physiological preconditioning of planting stock depends on lifting at the proper time, storing under appropriate conditions, and planting when RRP is highest. This paper reports the results of our study and discusses the feasibility of using RRP tests to evaluate nursery stock and its suitability for outplanting.

METHODS

5 Eleven bi-weekly liftings of 1-0 black walnut seedlings were made between October 6, 1976 and April 25, 1977, from the Vallonia Forest Nursery, near Brownstown, Indiana. The October 6 lifting was about 7 days before leaf fall and the April 25 lifting was about 10 days after flushing. Each lot of seedlings was graded to minimum stem caliper of 0.7 cm and root pruned to 22 cm. Twelve seedlings from each lot were potted at each of the following times: immediately, 4, 8, and 12 weeks after lifting, and on December 8, March 8, and May 12. Seedlings were stored at 3 C until potted.

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Root regeneration potential of these potted seedlings was determined by a method similar to that of Stone and Schubert (1959). The seedlings were placed in a greenhouse where a 16-hour photoperiod and a 24 C-soil temperature were maintained. Air temperature in the greenhouse varied seasonally (minimum 16 C). At the end of 4 weeks, the seedlings were unpotted. Total shoot elongation, stem caliper 2.5 cm above root collar, ovendry weight of all new roots, and ovendry weight of the total root system were measured for each seedling. Lifting date and storage treatments were compared for significant differences by analysis of covariance--total root dry weight was the covariable for root growth response and stem caliper was the covariable for shoot growth response.

RESULTS

Our study showed that date of lifting seriously affected the physiological quality of black walnut planting stock. Seedlings lifted from late fall (about 1 month after leaf fall) to the time of bud swell in spring maintained acceptable RRP in storage (fig. 1). Growth response was divided into two significantly ($P \leq 0.05$) distinct groups: (1) seedlings lifted on October 6 and 18 had low root and shoot growth, and (2) seedlings lifted between November 1 and April 25 had moderate root growth (differences among these nine lifting dates were nonsignificant) with moderate shoot growth in fall and significantly higher shoot growth in spring.

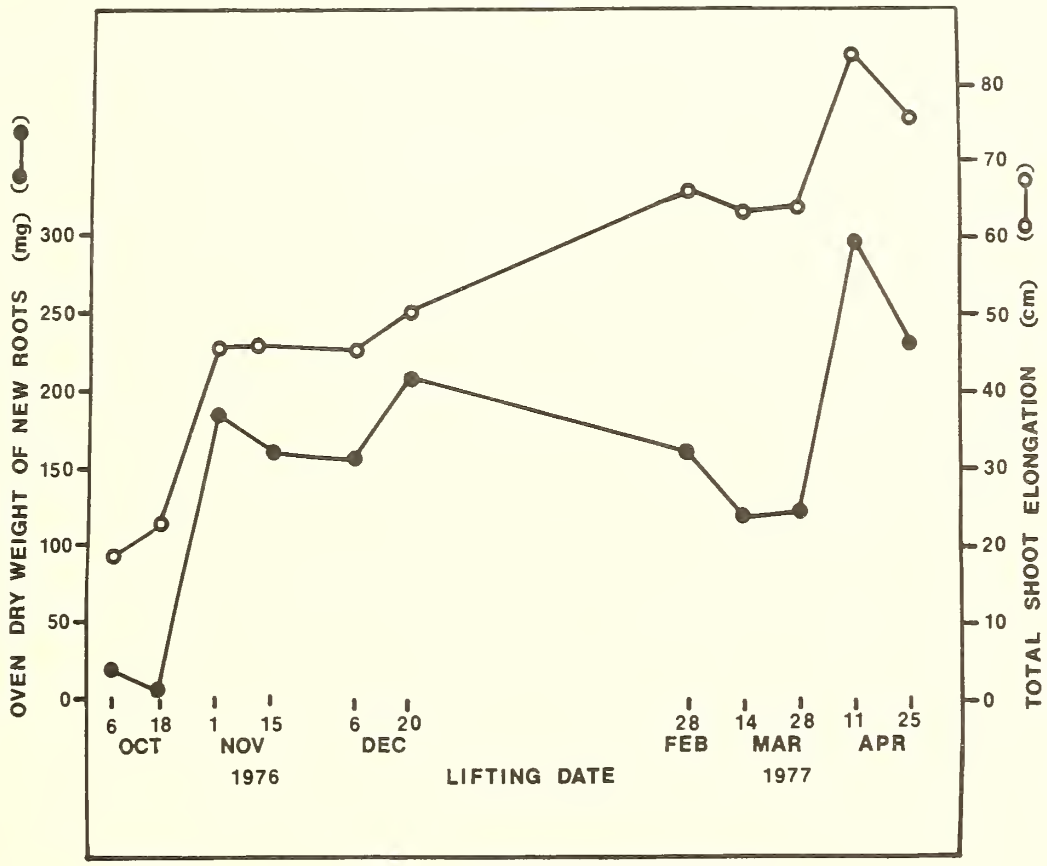

Figure 1.--Root regeneration and shoot growth potential of black walnut seedlings lifted on different dates and stored to May 12. Twelve seedlings representing each lifting date were potted and grown in a greenhouse for 4 weeks.

The best spring-lifting date for immediate planting or extended storage was just before bud swell. Seedlings lifted and stored then, on April 11, maintained the highest physiological quality in extended storage. RRP for these seedlings increased during storage (177 mg at lifting, 197 mg on May 12, 311 mg on June 6). In contrast, the seedlings lifted after flushing on April 25 declined with longer storage (249 mg at lifting, 231 mg on May 12, and 118 mg on June 20). The lowest RRP value would be considered unacceptable when compared to an average RRP of 182 mg for seedlings lifted between November 1 and April 25 (fig. 1).

All seedlings required exposure to cold temperatures for a definite amount of time before showing any growth in RRP tests. Seedlings stored to December 8 had no RRP because of inadequate chilling. In those stored to March 8, the chilling was minimally complete and RRP was uniformly low. In contrast, seedlings stored to May 12 (fig. 1) had vigorous root regeneration and shoot growth that differed significantly among lifting dates.

DISCUSSION

Seedlings lifted before November 1 had reduced vigor after overwinter storage. Although these seedlings received more chilling than seedlings lifted later, their RRP on May 12 was much lower. The seedlings lacked vigor because they were lifted too early and were not sufficiently cold-hardened to withstand lifting and cold storage. These results show that lifting date is an important factor affecting the quality of black walnut planting stock. Because the time when seedlings are ready for lifting varies from year to year and nursery to nursery, independent criteria are needed to determine lifting dates; research is underway to develop these guidelines. A rough criterion would be to wait 1 month after leaf fall before lifting black walnut seedlings.

Chilling is extremely important in determining the rapidity and total amount of root and shoot growth. When inadequately chilled seedlings are planted in a favorable environment, they resume growth slowly and then grow sluggishly. Stored black walnut seedlings need a minimum of 3100 hours of chilling at 3 C (Rietveld and Williams 1978); they need about 3500 hours for vigorous growth. Generally the more chilling the seedlings receive, the more rapidly they resume growth and the greater is their growth response during the 4-week test period.

Root regeneration potential seems to be a good way to evaluate the effects of lifting and storage on black walnut planting stock that has been adequately chilled. A method of evaluating the physiological quality of hardwood planting stock before planting time would be highly useful in culling low vigor stock. Such a method has been proposed for coniferous planting stock by Hermann and Lavender (1979). Based on an RRP-type test where seedlings are potted, this method relates planting stock quality to days to bud burst and survival after a specified period of time. A similar method could be devised for black walnut and other hardwoods, if the extremely long chilling process in hardwoods could be accelerated. Although most northern and western conifers require only 1000-2000 hours of chilling, most eastern hardwood species require 2500-3500 hours before vigorous growth will occur. Hardwood planting stock cannot be completely chilled, and RRP tests run and grading completed in time for early spring planting. Unless RRP tests can be completed in late winter before the spring planting season, their usefulness for other than research purposes is questionable.

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245

SEWAGE SLUDGE AFFECTS SOIL PROPERTIES AND GROWTH OF SLASH PINE SEEDLINGS IN A FLORIDA NURSERY

Charles R. Berry[1/]

Abstract.--The effects of dried sewage sludge in quantities of 68 and 136 mt/ha were compared to normal fertilizer applications on growth of slash pine seedlings in experimental nursery plots at the M. D. Andrews Memorial Nursery in Chiefland, Florida. The fertility treatments were combined factorially with two mycorrhizal treatments, natural inoculation or inoculation with vegetative inoculum of *Pisolithus tinctorius*. Sewage sludge increased initial soil concentrations of total N, available P, and exchangeable K, Ca, Mg, Mn, Cu, and Zn. Cation exchange capacity and pH were also increased, but organic matter was not significantly altered. Seedling diameters and fresh weights were larger in plots amended with 136 mt/ha of sewage sludge than when amended with fertilizer. Inoculation of seedlings with *P. tinctorius* increased top fresh weight in the fetilizer and 68 mt/ha sludge treatments. Concentrations of extractable elements in the Newberry, Florida, sewage sludge used in the experiment were compared to those of sludge from Athens, Georgia, and Norman, Oklahoma, to illustrate some of the differences in mineral composition that may be expected from sewage sludge produced in different areas.

Additional keywords: Ectomycorrhizae, cation exchange capacity, organic matter, *Pinus elliottii* ~~var~~. *elliottii*, *Pisolithus tinctorius*.

Sewage sludge is derived from organic and inorganic matter removed from wastewater at sewage treatment plants. The nature of the sludge depends on the wastewater source and the method of wastewater treatment. Nurserymen considering the use of sewage sludge as an organic amendment are particularly interested in the concentrations of plant nutrients, concentrations of toxic microelements, pH, percent organic matter, salt content, odors, and animal pathogens. Reasonable precautionary measures should be taken to guard against exposure to pathogens, although well stabilized sludges are relatively free of pathogens and odors.

Very little literature is available to furnish guidelines for the use of sewage sludge as a soil amendment in forest nurseries. In a loamy sand nursery soil applications of 224 and 448 mt/ha of screened compost (sewage sludge composted with wood chips) produced taller seedlings of yellow poplar (*Liriodendron tulipifera* L.) and flowering dogwood (*Cornus florida* L.) than 0 or 112 mt/ha of compost (Gouin and Walker 1977). Greater height of red maple (*Acer rubrum* L.) was obtained the following year using the same compost in the same unaltered nursery beds and at the same rate (224 and 448 mt/ha) than was obtained with 0 or 112 mt/ha (Gouin and others 1978). Total fresh weights of loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.) pine seedlings grown from seed were increased 4- to 6-fold by amending a clay soil with 138 mt/ha of sewage sludge in experimental nursery microplots (Berry and Marx 1976). In the same study, fresh weights of seedlings grown in plots amended with 69 or 275 mt/ha were significantly less than in plots amended with 138 mt/ha.

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Sewage sludge from different localities varies considerably in nutrient concentrations. Total N varies from 1.5 to over 6.0 percent, total P from 0.7 to 4.0 percent, total K from 0.2 to 0.7 percent, and organic matter from 20 to 70 percent. The concentrations of readily available elements (as determined by Plasma Emission Spectograph after double acid extraction) also vary as shown by analyses of sludge from Newberry, Florida; Athens, Georgia; and Norman, Oklahoma (table 1). Of particular interest are the high concentrations of P in the Florida sludge and the high levels of Ca, Mg, and Na in the Oklahoma sludge. The effects of these sludges on growth of loblolly pine are currently under study in Athens, Georgia.

Table 1.--Available elements in sewage sludge from three locations

Element	Athens, Georgia	Norman, Oklahoma	Newberry, Florida
	- - - - - - - -	ppm	- - - - - - - -
P	549	790	1,464
K	218	201	199
Ca	1,740	6,072	3,900
Mg	56	561	373
Mn	20	32	14
Zn	251	100	351
Cd	2	1	3
Al	327	7	328
Na	21	320	50
Cu	24	3	20

Inoculation of nursery beds with *P. tinctorius*, already shown to be of value in standard nursery operation (Marx *et al.* 1976) was carried out to determine whether beneficial interactions with sewage sludge would occur. This paper, therefore, reports an experiment testing the value of Newberry, Florida dried sewage sludge as a soil amendment interacting with inoculation with *P. tinctorius* for production of slash pine (*P. elliottii* Englem. var. *elliottii*) seedlings at the M. D. Andrews Memorial Nursery in Chiefland, Florida during the summer of 1979.

MATERIALS AND METHODS

Treatment plots 1.2 m x 1.2 m (4 ft x 4 ft) were arranged in a randomized block design in the second nursery bed in from an irrigation riser line. Three fertility treatments, (1) normal fertilizer application, (2) 2.5 cm (68 mt/ha) of dried sewage sludge, and (3) 5.0 cm (136 mt/ha) of dried sewage sludge, were combined factorily with two mycorrhizal treatments--natural inoculation and inoculation with vegetative mycelium of *Pisolithus tinctorius* (Pers.) Coker and Couch (Pt), isolate 246. Sewage sludge obtained from Newberry, Florida and stockpiled at the nursery in March 1979, contained 1.15 percent total N, 20.0 percent organic matter, and concentrations of other elements as noted in table 1.

Sewage sludge was placed on oversize plots (1.5 m x 1.5 m) and thoroughly disked into the soil. The plots were fumigated on April 4, 1979 with methyl bromide (Dowfume MC-2, Dow Chemical Co., Midland, Mich.) under clear plastic at the rate of 504 kg/ha.

Pisolithus tinctorius inoculum was produced by methods described by Marx and Bryan (1975). After the beds had been shaped on April 17, mycorrhizal inoculum was broadcast onto the soil and incorporated by hand tools into the upper 10 cm of soil at a rate of 1.08 ℓ/m^2 (100 ml/ft^2).

Sulfur was applied to the soil 3 weeks prior to bed preparation at a rate of 336 kg/ha to adjust pH. Fertilizer was applied to the fertilizer plots according to the current prescription for this nursery--168 kg/ha of 10-10-10, 112 kg/ha of superphosphate, and 336 kg/ha of Sul-Po-Mag[1/] prior to sowing; 168 kg/ha of NH_4NO_3 applied once in June and again in July; and 140 kg/ha Sul-Po-Mag applied once in July, again in August, and a third time in October.

Soil samples for chemical analyses were taken in all plots from the upper 15 cm of nursery soil after application of sludge but prior to application of preseason fertilizer.[2/] Seedlings were undercut, hand lifted, graded, and data recorded in January 1980. Data were analyzed by analysis of variance with means separation by Duncan's New Multiple Range Test. Ectomycorrhizae were visually estimated according to the procedure described by Marx and Bryan (1975).

Chemical analyses of seedling foliage and plot soil are being made from samples collected when the experiment was terminated, but are not available at this time. The results of these analyses will be published at a later date.

RESULTS

Five cm of sewage sludge applied to nursery plots increased soil nitrogen 3- to 4-fold, soil phosphorus 2½- to 3-fold, magnesium 3-fold, copper 20-fold, and zinc 20- to 30-fold (table 2). Organic matter was increased slightly, though not significantly, cation exchange capacity was doubled, and pH was increased in plots with 5 cm of sludge compared to nonamended plots, which later received fertilizer.

Slash pine seedlings grew better in plots amended with 5 cm of sewage sludge than in plots amended with fertilizer. Seedling density averaged 227 seedlings/m^2 (21/ft^2) and all plots had about 11 percent cull seedlings; treatment did not affect these parameters. Since seedlings were top pruned during the growing season, seedling height at lifting time did not differ between treatments. Seedling diameters and fresh weights, however, were significantly larger on plots that had received 5 cm of sewage sludge than on fertilizer plots.

Evaluation of seedling roots at lifting revealed that the percentages of short roots mycorrhizal with all fungi, with Pt and with indigenous species were relatively low. Although the degree of Pt infection was low in all treatments receiving Pt inoculum, it was lowest on seedlings from sludge treatment plots. Sporophores of Pt were found regularly late in the season in fertilizer plots, but were not detected in sludge-amended plots. In spite of the low level of Pt

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1/ Sul-Po-Mag is 18 percent magnesium sulphate as MgO with 21 percent water soluble potash.

2/ Soil samples analyzed by Dr. C. G. Wells, Forestry Sciences Laboratory, USDA Forest Service, Research Triangle Park, N. Car.

infection, however, seedlings from Pt infested plots had significantly greater top fresh weights than noninoculated seedlings in both the fertilizer-amended plots and plots amended with 2.5 cm of sewage sludge (table 3).

Table 2.--Soil analyses of experimental plots following application of sewage sludge but prior to application of fertilizer

Element	Control[1/]	Sludge 68 mt/ha	Sludge 136 mt/ha
N	297c[2/]	552b	1,072a
P	86c	153b	258a
K	22c	23b	30a
Ca	279c	504b	790a
Mg	13c	27b	44a
Mn	13a	13a	13a
Cu	2c	12b	24a
Zn	2c	21b	47a
O.M. %	0.8a	0.8a	1.2a
CEC me/100gm	0.7c	1.0b	1.4a
pH	4.9c	5.9b	6.3a

1/ After soil analyses fertilizer was applied to control plots.

2/ Means within the same line followed by the same letter do not differ at *P*=0.05.

Table 3.--Growth and ectomycorrhizal development of slash pine seedlings after 8 months in soil infested with *Pisolithus tinctorius* (Pt) and amended with dried sewage sludge

Treatment	Height (cm)	Root collar dia (mm)	Fresh weight (gm)			Percent short roots ecto-mycorrhizal with	
			Top	Root	Total	Pt	All fungi
NI[1/] with fertilizer	26.8a[2/]	5.1c	14.4d	3.2c	17.6b	0	33.2b
Pt with fertilizer	27.0a	5.9bc	18.9bc	5.0bc	23.9ab	14.5a	34.0b
NI-sludge 68 mt/ha	28.8a	6.0bc	18.2c	5.6ab	23.8ab	0	39.4ab
Pt-sludge 68 mt/ha	27.5a	6.8ab	20.8ab	5.9ab	26.7a	8.0a	34.6b
NI-sludge 136 mt/ha	26.0a	6.9ab	22.3a	7.8a	30.1a	0	47.6a
Pt-sludge 136 mt/ha	27.2a	7.2a	22.8a	7.5a	30.3a	7.3a	42.0ab

1/ NI - plots not inoculated with *Pisolithus tinctorius* vegetative mycelial inoculum.

2/ Means within the same column followed by the same letter do not differ at *P*=0.05.

DISCUSSION

Five cm of dried sewage sludge applied to plots at the Andrews Memorial Nursery stimulated more growth of slash pine seedlings than the normal fertilizer applications. Even though seedlings in plots amended with 2.5 cm of sludge were of good size and quality, only among noninoculated plots were top and root fresh weights significantly better than on fertilizer plots.

Although the degree of Pt infection was not high in any treatment, it was slightly lower in all sludge plots. In addition, the lack of Pt sporophores on sludge plots indicates either a lower rate of Pt colonization of roots in these plots or the presence in sludge of a factor that inhibits sporophore production. In spite of lower Pt colonization and lack of sporophore production, Pt was still responsible for greater seedling top fresh weights in the 2.5 cm sludge plots.

Amendment with sewage sludge did not increase soil organic matter as much as calculations had indicated. For example, a 2.5 cm application of sewage sludge weighing approximately 68 metric tons per hectare and containing 20 percent organic matter should, theoretically, increase soil organic matter in the upper 15 cm by 1.4 percent. Additional organic matter in sludge plots was barely detectable, possibly due to inadequate sampling techniques or analyses methods, when soil samples were taken 2 weeks after application. The increase in organic matter, even in the 5.0 cm application, was less than the expected increase in the 2.5 cm application.

The role of phosphorus in the production of seedlings that will perform well after outplanting continues to be of intense interest. We know that development of endomycorrhizae on sweetgum is suppressed when soil phosphorus concentrations are higher than 75 to 125 ppm (Kormanik, unpublished data). On the other hand, Marx (unpublished data) has obtained good Pt ectomycorrhizal development on pine in soils with phosphorus concentrations up to 125 ppm. Phosphorus concentrations in the nonamended soil and the Newberry, Florida sewage sludge were fairly high. Adding sewage sludge or superphosphate fertilizer to this soil may have resulted in levels of P that were inhibitory to Pt synthesis. The effect of increasing soil pH to 6.3 on Pt ectomycorrhizal development has not been established, but it is known that the fungus grows better under more acid conditions.

The most important result of this work, however, is that sewage sludge proved to be an excellent soil amendment for a sandy soil in a Florida nursery. Since past experience indicates that it should be just as effective in nurseries with soil having more clay (Berry and Marx 1976), more consideration should be given to the use of this valuable waste product.

Field performance is, of course, the final criterion for measuring the value of a nursery treatment. By fall of 1981 we expect to have data to evaluate initial field performance of the trees produced in this experiment.

A large part of the 2.2 million metric tons of sewage sludge produced annually in the United States should be suitable for forest nursery use. In the future we will continue to evaluate sludge from different areas in different soils to acquire a better understanding of its use in nurseries and elsewhere. The relationship of soil phosphorus concentrations, organic matter, possible phytoxicity of heavy metals, and possible deleterious pH effects must be determined before this byproduct of society can be considered useful in forestry.

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ORGANIC MATTER IN NURSERY SOILS

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I will not consider the advantages of organic matter in the soil as it has been discussed thoroughly at several of the Nurserymen's Conferences. In this paper I will discuss how to maintain or increase the organic matter content of the soil.

The minimum levels of organic matter in soils of southern nurseries should be:

1.0 to 1.5 percent for sands and loamy sands.

2.0 to 2.5 percent for sandy loams.

3.0+ percent for loams and heavier textured soils.

These levels are considerably lower than organic matter levels of nursery soils in colder and/or drier climates and may be below optimum levels. Only a few nursery managers have seriously attempted to maintain the organic matter content of the soil at the above levels. This phase of nursery management has received about as much attention as a poor relative.

The best means of increasing organic matter in nursery soils are (1) with the use of soil additives, (2) with a combination of soil additives and cover crops and (3) with cover crops alone.

Factors which must be considered as one develops a system of maintaining the organic matter are:

1. Type of rotation.
2. Availability and use of soil additives.
3. Types of cover crops.
4. Time of sowing of cover crops.
5. Maintenance of cover crops.
6. Harvest of cover crops.
7. Cost of alternative systems.

1. <u>Type of rotation</u>

Previously we thought that a 1 : 1 (1 year seedlings and 1 year cover crop) rotation was adequate for maintaining the productivity of a nursery soil. Later we found that sawdust, peat, chicken litter or other additives were needed in conjunction with a good cover crop.

The advent of methyl bromide made the 2 : 2 rotation popular. This type rotation spread the cost of fumigation over two seedling crops. Also, it allows the growing of three cover crops during the two-year period. The system functions well when additives are available and the lifting is completed in February and sowing of tree seed is done in April. The time interval is adequate for soil preparation plus fertilization. The system does not work well when lifting extends into late March and April.

Rotations such as 2 : 1, 3 : 1, and 4 : 1 developed from necessity as production increased while the seedbed area remained constant. Without exception, these rotations eventually resulted in a reduction of soil fertility.

The present trend is toward a 1 : 2, 1 : 3 or a 2 : 3 rotation. This system requires more cultivatable land but provides more flexibility in maintaining soil productivity.

2. Availability and use of soil additives.

Each nursery can be considered an island. Some are close to sources of organic additives; others are not. The cost of delivering sawdust, bark, etc. differs for each nursery. At what point on the dollar scale does the cost eliminate the use of these additives?

The classic example of the use of soil additives is the use of peat. Many nurseries in the Lake States, Canada, England, Sweden, Norway and Finland are located near sphagnum swamps or peat bogs. Peat is excavated using draglines or rubber-tired equipment. The method of mixing and applying peat or compost varies with the equipment and facilities available. The simplest method is to apply 60 to 200 cubic yards per acre directly on the nursery site with a manure spreader and incorporate the peat into the soil with disks, cultivators or harrows. An alternative is to compost peat or mixtures of peat and other materials for several weeks, months, or even up to two years.

In the southern region, soil additives have included sawdust, chips, shavings, post peelings, bark, shredded pine cones, peat, chicken litter, bagase, grain straw, tobacco plants, manure, sewage sludge and possibly other materials. Many of these additives are now used in the manufacture of pulp or for fuel and are not available for use in a nursery.

Most soil additives contain low levels of plant nutrients and have a high carbon/nitrogen (C/N) ratio. Peat, for example, has a wide C/N

ratio ranging from about 20/1 to 75/1, depending on the original plant material and the degree of decay. Sawdust has a C/N ratio of about 400/1, dead pine needles - 225/1 and dead oak leaves - 65/1. Most other additives have C/N ratios between that of peat and sawdust.

Many soil additives are most effective when used in conjunction with a cover crop. At the Auburn (J. M. Stauffer) Nursery, 100 cubic yards of sawdust per acre followed by a summer cover crop in a 1 : 1 rotation maintained the organic matter content of the soil at a constant level for years.

3. Cover Crops.

Prior to the 1960's, the principal cover crops were field peas, velvet beans, soy beans, crotalaria, sesbania, Austrian winter peas, hairy vetch, rye and oats. Yields of green matter ranged from 8 to 20 tons per acre (2 to 5 tons O.D. matter).

The cover crops of today produce greater yields of green matter per acre and contain more fiber. Some varieties of corn and sorghum grow 10 to 15 feet tall and produce yields of 40 to 55 tons of green matter per acre (10 to 14 tons dry matter).

The most frequently used summer crops on a 1 : 1 rotation are sorghum-sudan grass hybrid (sudex), millet (Gahi, Pearl or Tift), silage corn and silage or grain sorghum.

For a 1 : 2 or a 2 : 2 rotation, a good combination is corn or sorghum during the first summer; followed by rye, wheat, or oats in the winter; and sudex or millet during the second summer.

In selecting a cover crop, the nursery manager should consider the approximate days to maturity. Sorghum-sudan grass hybrids mature in about 50 days unless the plants are clipped or mowed. Under good conditions, the hybrids often grow more than a foot a week and can yield two tons of dry matter (15 tons of green weight) per acre per month if clipped and fertilized regularly. Corn varieties are grouped into three maturity dates, namely Early (85 to 100 days), Mid-season (100 to 120 days) and Full-season (120 to 140 days). Silage sorghum will mature in about 70 days unless mowed. Grain sorghum matures in 90 to 120 days depending on the variety.

Four new varieties of vetch have been developed as green manure crops or cover crops for soil building purposes. These are resistant to many of the parasitic nematodes and act as a trap crop for nematodes. They can be

overseeded in standing row crops of corn or sorghum; but they do better on a well prepared seedbed. They can be interseeded with rye, wheat or oats.

Different varieties of corn, sorghum, rye, millet, vetch and sorghum-sudangrass hybrids are developed for different climatic and soil zones. Nursery managers should consult the Agricultural Extension Specialist and local seed dealers for the varieties best suited for their nursery.

4. Time of sowing.

A critical factor in the establishment and growth of cover crops is the time of sowing. Nursery managers tend to delay sowing of cover crop seed until after the tree seed are sown. Then it may be too late to get good germination without irrigation. The best time to plant in the deep south is in March or April; or when the soil temperature is above 65° F. at seed depth.

5. Maintenance of cover crops.

Cover crops require nutrients, water and freedom from weed pests. A 25 ton silage corn crop removes 200 pounds of nitrogen, 75 pounds of phosphate and 150 pounds of potash per acre. Fertilizers can be applied as a preplant application or as a side-dressing early in the growing season. When side-dressing corn or sorghum with a ground rig, apply fertilizer to the row middles to avoid root pruning.

A lack of water at the critical time has resulted in a failure or in a poor yield. Cover crops need water for germination of seed. Water is needed for growth when the soil has reached 25 to 50 percent of its available water capacity. Each nursery should have sprinklers available for irrigating the cover crop. One or more portable big gun nozzles may be adequate.

Weed control in the cover crops is as essential as it is in the seedling crop. Choose the best herbicides possible for your soil type(s), cover crops and weed species.

6. Harvest of cover crops.

The stage of development of the cover crop when it is cut or plowed under is extremely important. For the most part, the carbon/nitrogen ratio of plant tissue reflects the kind and age of the plant from which it was derived. The normal consequence of plant maturation is a decrease in the protein (N) content and a build-up of carbonaceous structural tissue high in cellulose and lignin. For these reasons aging results in the gradual decrease in the susceptibility of plant tissue to decay and a paralleling

increase in the C/N ratio. C/N ratios associated with some cover crop tissue are:

Young rye plants	20/1
Mature rye plants	350/1
Legumes	25/1
Corn stalks	40/1 to 60/1

If a soil additive with a high C/N ratio is mixed with the soil prior to sowing of the cover crop or late in the season, maximum microbial action will occur if the cover crop is turned under when still green. If the objective is to add maximum amounts of slowly decomposable material, the cover crop should be left until full maturity. Some nursery managers reduce the cost of the cover crop by selling the seed produced on the crop. In some varieties of corn approximately two-thirds of the nutrients and one-half of the feed tonnage is concentrated in the ear. The question is - will the dollar value of 50 to 100 bushels of corn be sufficient to offset the removal of nutrients from the soil?

7. Cost of alternate systems of maintaining soil organic matter.

To date there is not enough information to make reasonable comparisons of the potential systems, i.e.:

1. Use of soil additives only (sawdust, bark, etc.).
2. Use of soil additives plus cover crops on a 1 : 1 or a 2 : 2 rotation.
3. Use of cover crops alone on a 1 : 2, 1 : 3 or a 2 : 3 rotation.

We must obtain yields from cover crops over a period of several years before reliable comparisons can be made. This will require sufficient acreage for a 1 : 2 and a 1 : 3 rotation; intensive sampling of the soil; and finally the production of good cover crops, i.e. yields of 30 to 50 tons of green material per acre during the growing season. The Auburn University Nursery Coop., in 1980, initiated a long term study of cover crops in nurseries in Alabama, Georgia, and South Carolina.

NURSERIES WITH WORN-OUT OR UNPRODUCTIVE SOIL

Continuous seedling production on the same land is beginning to create some serious problems in some nurseries. Seedlings are stunted, chlorotic and infected with root-rot and have a high mortality. Soil organic matter is usually low and nutrient ratios are frequently out of

balance. These sites need a crash program to rebuild productivity of the soil. The best program is with the use of soil additives which have been composted.

In the 1930's compost pits were used for material such as peat, bagase, etc. The process required one to two years. Chuck Davey described a more useful process in 1952 and again in 1955. He stated that "Anhydrous ammonia was applied at the rate of 12 to 15 pounds per cubic yard of sawdust. Then after letting the sawdust stand for several days, phosphoric acid was added in dilute solution in sufficient amount to bring the reaction down to approximately pH 8. Then one pound of potassium as potassium sulfate was added to complete the addition of the major nutrients, nitrogen, phosphorus and potash. Also, a mixture of minor elements, at one pound per cubic yard, was added. This chemically treated or enriched sawdust was then inoculated with Coprinus ephemerus, which in the presence of abundant ammonia is a very active cellulose decomposer. Within six weeks, under favorable climatic conditions, a majority of the cellulose was removed; the carbon-nitrogen ratio was lowered to approximately 20; and the cation exchange capacity, that is the ability to hold nutrients against leaching, was increased at least 100 percent".

Charles Berry has just discussed sewage sludge. This is timely for both nurseries and for planting operations on adverse sites, especially since cities and states are faced with the problem of disposing of increased amounts of waste (garbage and sewage sludge) on less and less land.

Grinding the material to be composted speeds its decomposition by increasing its surface area and hence its susceptibility to microbial invasion. Moisture content of the material is important in composting - with optimum contents of 50 to 60 percent moisture content (wet weight). Oxygen is required by aerobic microorganisms during the decomposition process. Windrows 7 feet wide and 5 feet high can be aerated by turning or thoroughly mixing by mechanical means. Two to three turns per week can maintain the aerobic state. Methods of handling material vary, depending on the ratio of carbonaceous material to nitrogenous material. The "Berkely" method can produce compost in two weeks. Other methods may require up to three months.

Compost should be "ripened" before being applied to the soil as it undergoes further changes in composition after it has been cooled to ambient temperature. The time of ripening varies from two to seven weeks.

Municipal and industrial waste may contain pathogens, parasites and heavy metals which can cause problems. Composting can destroy many pathogens and change the chemistry of the material. However, use of these waste materials should be carefully monitored.

COVER CROP VARIETIES IN USE IN THE LATE 1970's

Silage corn	Sorghum	Sorghum-sudan grass hybrid	Millet	Vetch	Rye
Coker 54 and 57	Acco FS 531	Acco Sweet Sioux IV	Gahi	Cahaba White	Abruzzi
DeKalb XL 395	DeKalb D-60	Funk's 83F	Pearl	Nova II	Ebon
Funk's G 4776	DeKalb FS-25a	Funk's 86F	Tift	Vanguard	
Golden Harvest H 2775	Funk's 99S	McCurdy Sweet M	McCurdy Grazex	Vantage	
McCurdy 72A	McNair HO-K	Northrup-King Sordon 70A	NAPB Pearlex 24		
	NAPB 55F	Northrup-King Trudan 5	Ring Around Millhy		
	Northrup-King 367	Ring Around Super Chowmaker			
	Pennington Pennsilage A	Taylor-Evans Haygrazer			

SOME SOURCES OF COVER CROP SEED

Acco Seed Co.
P. O. Box 1630
Plainview, TX 79072
or Rte. 1, Champaign, Illinois 61820

Coker's Pedigreed Seed Co.
Hartsville, S.C. 29550

Columbia Seed Co. (Golden Harvest)
Eldred, Illinois 62027

DeKalb Agricultural Research, Inc.
Rte. 3, Box 132
Leesburg, GA 31763

Everett Seed Co. (Imperial)
P. O. Box 90992
Atlanta, GA 30344

FMC Corporation (Oro)
Agricultural Chemicals Division
6065 Roswell Road N.E.
Atlanta, GA 30328

Louisiana Seed Co., Inc. (Funk's)
P. O. Box 7498
Alexandria, LA 71301
(Distributors throughout the south)

McNair Seed Co.
P. O. Box 706
Laurinburg, N.C. 28352

Northrup - King & Co.
P. O. Box 151
Columbus, MS 39701

Pioneer Hi-bred International, Inc.
221 N. Main St.
Tipton, Indiana 46072

Pennington Seed Co.
P. O. Box 290
Madison, GA 30650

Ring Around Products, Inc. (Choumaker)
Reynolds Mill Road
Prattville, AL
or P. O. Box 1629
Plainview, TX 79072

245

A Progress Report: Effect of Rate and Kind of Hydromulch on Germination of Southern Pine Seed

by

100 S. J. Rowan[1/]

Abstract.--Turfiber, Hydromulch and Cellin mulch materials were found to be equally good for the germination of slash and loblolly pine seeds in Georgia nurseries. Pine straw was not as good for seed germination as these other mulch materials, but previous results indicate that pine straw is the superior mulch material if heavy rains occur shortly after beds are seeded.

In a recent publication, I reported that sawdust and pine straw were better seedbed mulch materials than was Hydromulch, and that the planting of seeds at a 1/4-inch depth increased the number of seedlings established per linear foot of bed (Rowan 1980). The primary reason for this increase was that fewer seeds were washed from seedbed surfaces during heavy rains when seeds were planted deeper or mulched with pine straw or sawdust.

In an attempt to determine if these findings were applicable to normal nursery operations, a study was established on 39 seedbeds ($\geq$520 feet in length) in each of the two Georgia Forestry Commission

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The author is indebted to the Georgia Forestry Commission for funding this research and expresses appreciation to personnel at the Walker, Morgan, and Great Southern nurseries for their assistance.

nurseries. Slash and loblolly pine seeds were sown at the Walker Nursery; only loblolly pine seeds were sown at the Morgan Nursery. Pine straw was applied at a 1/2-inch depth, and Turfiber and Hydromulch were applied at 1600, 1800, and 2000 lbs per acre on three replications at each nursery. At Great Southern's nursery, Cellin and Hydromulch were applied at 1500 lbs per acre to paired seedbeds of slash and loblolly pine. Seedling counts were made on random 1- x 4-foot areas in each bed in the Georgia Forestry Commission nurseries and on random 1- x 2-foot areas in Great Southern's nursery.

Effects of planting depth on seed germination were studied in the two Georgia Forestry Commission nurseries by setting one of the drill shoes of the Whitfield seeder at the Walker nursery to plant seed at a 1/4-inch depth. The other 7 shoes were set to plant at the soil surface. Two drills were planted at this deeper depth at the Morgan nursery. The rate of germination of seed in these drills was compared to the rate of germination of the same drills on the opposite side of the seedbed. The beds were planted so that the deeper drills were randomly on the right side of one-half of the beds and on the left side of the remaining beds. The effects of drill location in respect to bed edges was also determined in this study.

The results of this study are in preparation for publication in Tree Planters's Notes. Results indicate that because of the lack of heavy rains during the period of seed germination, pine straw was not superior to Turfiber or Hydromulch and, in fact, was inferior in one of the two Georgia Forestry Commission nurseries.

The lowest rate of either Turfiber or Hydromulch was as good for seed germination as was the highest rate of either mulch material. Neither was any difference found between Cellin or Hydromulch for seed germination. Thus, price and ease of application appear to be the criteria for mulch materials if seeds are planted at a 1/4-inch depth. The 1/4-inch planting depth was inferior to the normal surface planting at one of the two Georgia Forestry Commission nurseries. Thus, the deeper planting depth may be beneficial during heavy rains to prevent excessive washing of seed from the seedbed surface when Hydromulch or similar material is used, but this deeper planting depth may slow the rate of germination and decrease total germination.

Although, theoretically, equal numbers of seed were sown in each drill across the seedbed surface, the pattern of seedling distribution indicates that seeds moved toward the lowest points on the bed surface because of irrigation and rain. Seedbeds should, therefore, be as level as possible in respect to field slope and bed centers should be slightly lower than bed edges.

Literature Cited:

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EFFECTS OF NURSERY PRACTICES ON VESICULAR-ARBUSCULAR MYCORRHIZAL DEVELOPMENT AND HARDWOOD SEEDLING PRODUCTION

Paul P. Kormanik[1/]

Abstract.--Many hardwood tree species, i.e., sweetgum, ash, sycamore, maple, and yellow poplar, that are difficult to grow in forest tree nurseries are known hosts for vesicular-arbuscular mycorrhizal fungi (VAM). Seedling quality of these species can be significantly improved if nursery practices are modified to assure proper soil environmental conditions, not only for the hardwood seedlings, but also for the VAM fungi that are indigenous to the nursery. Soil fumigation, available phosphorus levels, rate and source of nitrogen, and soil pH interact with the hardwood hosts and VAM fungal symbionts. Certain guidelines can be useful for developing specific management practices for a specific nursery.

Additional keywords: Hardwood seedling quality, herbicides, fertilization, fumigation.

Substandard planting stock is perhaps the major silvicultural obstacle to artificial regeneration of hardwood species that are hosts for vesicular-arbuscular mycorrhizal fungi (VAM). Among these species are sweetgum, ash, maple, cherry, walnut, sycamore, and yellow poplar. To a great degree the establishment of a hardwood plantation depends on the nurseryman, his practices, and his personnel. Nowhere in the growing and planting sequence is the opportunity for quality control greater than in the nursery. To establish hardwood plantations, we must employ nursery production techniques that provide quality seedlings.

During the past 5 years, the Institute for Mycorrhizal Research and Development, U.S. Forest Service, Athens, Georgia has been developing a VAM technology for hardwood tree seedlings produced in nursery soils. When I addressed this group in 1976, I could only describe the work we were initiating and make broad recommendations--we had little practical experience or completed research. Now, 4 years later, our research results indicate that my earlier broad recommendations were, for the most part, correct. We have found that growing high quality hardwood seedlings is not the impossible job it was once thought to be. However, nurserymen will have to be flexible, willing to alter nursery practices and to develop standards for their own nursery based on specific soil and environmental conditions. A single, regionwide prescription for VAM technology transfer may not be possible.

If our research in simulated nursery beds is directly transferable to operational nurseries, most nurserymen should be able to produce large hardwood planting stock for the 1981 growing season. By 1982, nurserymen should be producing high-quality hardwood seedlings with the same consistency achieved with pine seedlings. Of course, there will be some production problems with hardwood species, but they should be no more severe than those encountered with pine. The possible adverse effects of high water tables and weed control practices may be the biggest problems to overcome.

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Some believe that large seedlings and high quality seedlings are synonymous, but this is not necessarily true. Initial results from our field performance trials suggest that a large seedling is not always a quality seedling. Our research shows that presence of VAM is the key to production of seedlings that will thrive after outplanting. Mycorrhizal technology has greater application than simply growing quality seedlings, but for the purpose of this paper other aspects will be, whenever possible, ignored. Items of direct concern to the nurseryman's immediate problem of growing VAM hardwood hosts will be discussed and, hopefully, clarified.

Today, most plant scientists realize that VAM are essential for normal development of specific tree hosts. We have had problems in forest tree nurseries producing hardwood seedlings because of cultural or management practices that, at least in the short run, reduce the effectiveness of the indigenous VAM fungi. Until recently we did not know what these practices were and, therefore, could not make the necessary cultural adjustments. Until the problem areas were isolated, we did not know how to make short-term nutritional adjustments while maintaining the long-term viability of the indigenous VAM fungal populations to assure quality seedling production.

The state of the art may change, but right now we think that efforts should be concentrated on building up and preserving whatever VAM fungi are indigenous to a particular nursery. Whatever benefits seedlings obtain from VAM, all species of VAM fungi appear to be equally effective as far as seedling development is concerned. Some VAM fungi may prove to be especially beneficial in particular circumstances. Some, for example, may be helpful in defending tree roots against disease. We are studying this possibility, but even if we found an exceptionally aggressive and beneficial VAM fungus, it would be of little immediate importance because we do not yet know how to introduce a single VAM into nursery soils. What is needed now in nursery production is a means of maintaining high population densities of indigenous VAM fungi that can infect roots early in the growing season. All hardwood nursery soils have the potential to develop and maintain a viable VAM population. Various cultural practices in a nursery, however, may significantly influence the effectiveness of VAM fungi. Cultural practices that must be considered are fumigation, weed control, fertilizer application, and maintenance of soil pH. Some of these practices affect only one member of the symbiotic partnership (host or fungus), while others affect both.

Fumigation and Weed Control

Fumigation creates problems when one is trying to retain VAM fungi because the treatment is indiscriminate--it kills beneficial as well as harmful soil fungi. The practice is necessary for control of root diseases, but it should probably be limited to the minimum necessary for disease control. Fumigation could be restricted to years when soil assays reveal a buildup of potentially harmful organisms in the soil.

Fumigation for weed control should probably be avoided whenever possible. It is an expensive practice for this purpose, and South and Gjerstad (1980) believe that few nurseries have enough weed or disease problems to justify annual soil fumigation. Nurserymen must find suitable substitutes for controlling weeds in hardwood crops. Herbicides may be a possibility. We have not undertaken any studies to determine how specific herbicides affect VAM fungi in the soil.

Management practices that increase nutrient availability in the soil are required for successful hardwood seedling production. VAM fungi are just one of the soil related factors involved in plant nutrient relationships. Any severe imbalance of essential elements is likely to adversely affect development of host and VAM fungi. Small imbalances are often more readily tolerated by mycorrhizal plants than by nonmycorrhizal plants.

Phosphorus

VAM are important in nutrient and water uptake by hardwoods. One of the most critical elements in VAM and hardwood growth in almost all soils is available phosphorus. It is not surprising that plant responses to VAM are especially dramatic when soil phosphorus is in the normal range. Most natural forest soils in the Southeastern United States have less than 8 ppm of available phosphorus. Without VAM, host trees could not become established and grow at these soil P levels. In some nonforest host plants, unusually high threshold levels of soil P are needed for the plant to develop in the absence of VAM. For about 4 years we have been trying to pinpoint these threshold levels for hardwood seedlings grown under nursery conditions.

Originally we grew hardwood seedlings requiring VAM at 25 to 30 ppm available P (Bray II). We obtained good quality seedlings at these levels with VAM, but nonmycorrhizal seedlings were stunted, seldom exceeding 7 cm in height. During the past 5 years we have run a series of experiments that standardized soil P levels at from 12 to 1000 ppm. The latter rate is equivalent to about 2000 pounds per acre of actual P. When soil P exceeds 200 ppm, VAM development can be drastically reduced, but 10 to 35 percent of the roots of most seedlings may have VAM. At soil P levels at 40 to 100 ppm, VAM roots can be somewhat reduced, but at least 40 to 75 percent of the roots of most seedlings can be colonized with VAM fungi. The latter range is the soil P threshold at which many tree seedlings grew as well without VAM as with them.

At this time, I recommend that nurserymen maintain soil P at 75 to 100 ppm. This level will permit seedlings to develop VAM even in soils where low levels of inoculum are present. We currently do not know what will happen in the long run to the VAM fungi reproduction when high levels of soil P are maintained. For example, with most VAM fungi we have worked with there is a reduction in spore production even at levels of 10 to 100 ppm soil P. With one particular isolate of *Glomus etunicatus*, spore counts declined (15,000, 2700, 800, and 125) as amount of available P increased (12, 25, 50, and 100 ppm). Other fungi did not show this reduction and, in fact, reproduced as well at 100 ppm of soil P as at 25 ppm. We can realistically hope, based on Schenk's (1980) work, that VAM fungi best adapted to the local environment and cropping sequence will be maintained and become the dominant species in a given nursery. I recommend that P not be added to the soil when cover crops are grown if soil during the seedling rotation is initially adjusted to approximately 75 ppm.

Nitrogen

Most nurserymen do not use enough nitrogen to obtain optimal hardwood seedling development. When a hardwood seedling has sufficient phosphorus to develop, it is biologically irrelevant whether the phosphorus is from heavy applications of phosphate fertilizer or from improved uptake through VAM. In either case, plenty of nitrogen is needed throughout the summer for optimal growth (Brown 1979). In our tests, we have found that if nitrogen is severely

restricted, sweetgum seedling development is as adversely affected as if both P and VAM are lacking.

As a general rule, 1500 lbs/acre of NH_4NO_3 (500 lbs N/acre) are adequate for VAM hardwood seedlings. This total should be divided among 10 applications throughout the growing season. It is important to include 3 applications in August and 2 applications in September. We believe that these late applications are essential because it is during this period, after the seedlings' root systems are well established, that at least 60 percent of total height growth occurs. The last NH_4NO_3 application should be scheduled 45 to 50 days before the first frost.

We have experimented with 125, 250, 500, 1000, and 2000 lbs/acre of N in different studies. These rates have been applied as NH_4SO_4, NH_4NO_3, and K NO_3. The latter N source has proven to be completely unsatisfactory for sweetgum and we doubt that it would be suitable for other species. Both NH_4SO_4 and NH_4NO_3 work equally well at rates up to 500 lbs/acre. At higher rates, NH_4NO_3 is better than NH_4SO_4. However, we do not recommend using NH_4SO_4 in acid soils; it reduces pH drastically.

Some technological changes in fertilizer processing have resulted in more frequent occurrences of sulfur deficiencies in hardwood nurseries. The use of NH_4SO_4 as a nitrogen source may reduce the chances of this in some nurseries. A workable solution might be to apply 50 percent of the nitrogen as NH_4SO_4 and the rest as NH_4NO_3.

Brown (1979) found that the growth response curve for sweetgum was still increasing at 500 lbs/acre of N with both NH_4NO_3 and NH_4SO_4, but that at 1000 lbs/acre in either form a pronounced depression was observed. At 2000 lbs/acre N, the growth depression was very pronounced. We have, however, observed a doubling of sweetgum height growth when N is increased from 125 to 250 lbs/acre, and a 50 percent increase in height growth when N is increased from 250 to 500 lbs/acre. The latter increase in height growth is accompanied by a substantial increase (ca. 40 percent) in root collar diameter; this may justify the added N cost.

Soil pH

In addition to its effect on nutrient availability, maintenance of suitable soil pH may also be quite important for indigenous VAM fungi. This possibility is difficult to assess. VAM synthesis occurs on plants in soils with wide pH ranges throughout the world. Thus, it can be reasoned that soil pH *per se* is not detrimental to VAM synthesis if the VAM fungi are still effective. Our research indicates that nursery soil pH should not be raised much beyond natural pH in a specific nursery. I suggest that nurserymen in the Southeast try to keep nursery soil pH between 5 and 6 and become concerned when over half of the soil samples have a pH consistently above 6.

In one experiment (Yawney 1980), an isolate of *Gigaspora margarita* obtained from a cotton field (pH 5.4) was tested at four soil pH levels--4.5, 5.5, 6.5, and 7.5. At the two lowest pH levels, VAM synthesis was good and sweetgum seedling growth response was quite satisfactory. At the two higher levels, the growth response to VAM was negligible and the seedlings were only slightly larger than the nonmycorrhizal controls (less than 10 cm).

No information is available on how soil pH affects reproduction of other VAM fungi that occur in nursery soils. Perhaps all species of VAM fungi will not be as sensitive as this particular isolate of *G. margarita*. However, it is relatively simple and inexpensive to monitor soil pH; I suggest that nursery

personnel do so during the growing season, especially after fertilizer application. The data could be important when viewed in a complete soil maintenance program and could be invaluable in determining the optimum pH range for VAM synthesis and specific hardwood seedling development in each nursery.

It must be emphasized that VAM fungi occur and form mycorrhizal associations in soils exhibiting a wide pH range. Therefore, regardless of the natural soil pH at a specific nursery, a good complement of well-adapted VAM fungi can be expected to be present. This population can be readily maintained by avoiding radical changes in soil pH.

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Schenck, N. W., and Kinlock, R. A. 1980. Incidence of mycorrhizal fungi on six field crops in monoculture on a newly cleared woodland site. Mycologia 72:445-456.

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New Applicators for Weed Control in Forest Nurseries and Plantations

J. M. Chandler and T. H. Filer

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USDA-SEA-AR, and Plant Pathologist, Southern
Hardwood Laboratory, USDA-FS, Stoneville, MS.

Until recently chemical weed control technology in forestry nurseries was limited primarily to soil fumigation, a very expensive and laborous weed control procedure. Herbicides for preemergence application have been registered and are currently being used to control many annual weeds. Removal of perennial weeds such as nutsedge, (*Cyperus* spp.) bermudagrass [*Cynodon dactylon* (L) Pers.] and johnsongrass [*Sorghum halepense* (L) Pers.] is still accomplished by hand labor which is very expensive and increasingly difficult to obtain. Our objective was to evaluate and/or develop equipment to apply non-selective herbicides selectively in forest nursery stock.

The Stoneville Wiper was developed in 1978 to make post-emergence band applications of non-selective herbicides in various row crops from the cotyledon stage through layby (Figure 1). The Stoneville Wiper was utilized in 1979 to treat a very dense stand of broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash], large crabgrass [*Digitaria sanguinalis* (L.) Scop.], and goosegrass [*Eleusine indica* (L.) Gaertn.] in black walnut (*Juglans nigra* L.) seedling beds at Baucum Nursery, Little Rock, Arkansas. Glyphosate at 3 lb/A applied with the Stoneville Wiper without the carpet to grass 28 to 36 inches tall in mid August resulted in 70% control 30 days after application. Grass control of 90% was obtained when the grass was only 4 to 10 inches tall. Blackwalnut seedling injury was limited to leaflets that were pulled under the applicator. In late August hand weeding data indicated that $1350 per acre would be required to clean the beds. The cost per acre for the glyphosate treatment was approximately $30 per acre.

During 1980 the Stoneville Wiper was utilized with and without the carpet in a cottonwood (*Populus deltoides* Marsh.) nursery (Figure 2). Glyphosate application at 1 to 3 lb/A was made to winter annuals. The lower rate did not provide adequate control. A hooded sprayer that covers an area 40 inches wide was built to apply herbicides to the middles between the cottonwood trees in mid summer (Figures 3 and 4). This applicator consist of a fiberglass hood 40 inches by 12 inches and 9 inches tall with nozzles mounted in the top 8 inches apart. Glyphosate at 2 lb/A gave 90 to 100% control of all vegetation present which included johnsongrass.

The "Two-in-One" applicator was designed and developed to treat a 4-inch band between pine (*Pinus* spp.) seedlings planted in rows 8 inches apart on a four foot bed (Figure 5). Individual applicator units, attached to an oiling bar arm, consist of an enclosed PVC pipe hood, a spray nozzle, and a 4 inch by 14 inch piece of nylon carpet with 3/4 inch fibers (Figure 6). The cone spray nozzle, mounted into the top-front portion of the PVC hood, delivers herbicide solution onto the back of the carpet that is attached face down over the lower part of the unit. When the carpet is removed, the herbicide can be sprayed directly onto the weeds. Preliminary work at W. W. Ashe Nursery, Brooklyn, Mississippi shows the unit has potential utility in the control of bermudagrass and nutsedge. No injury was observed on the pine seedlings.

In nursery situations where the weeds are taller than the nursery stock a newly developed applicator called the Ultimate Stoneville Applicator is being evaluated.

Editor's note: Plans of the Stoneville Wiper are available from: USDA Forest Service, State and Private Forestry, Rm. 300, 1720 Peachtree Road, N.W., Atlanta, Georgia 30367.

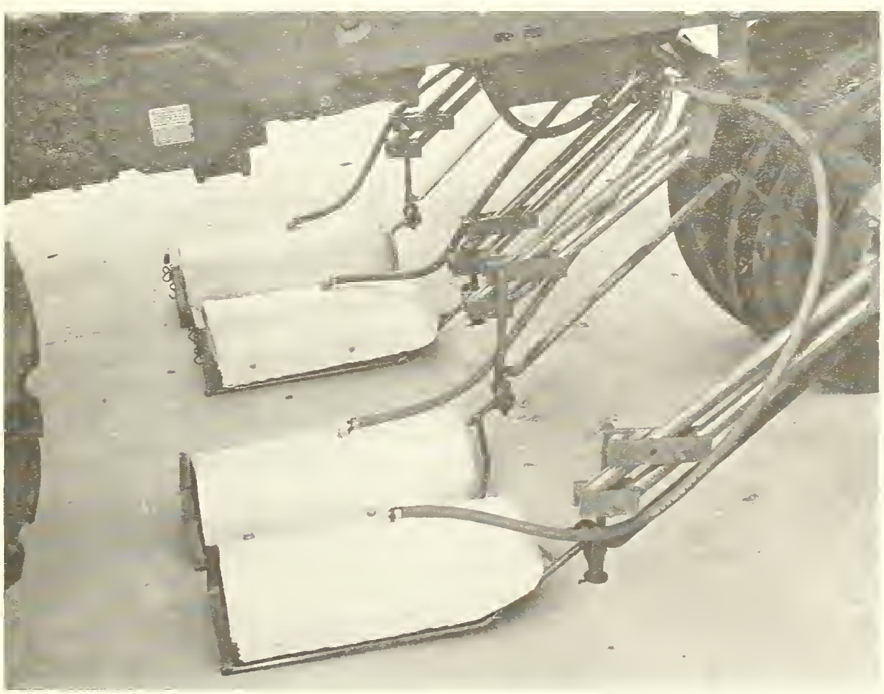

Figure 1. Stoneville Wiper mounted under front of tractor.

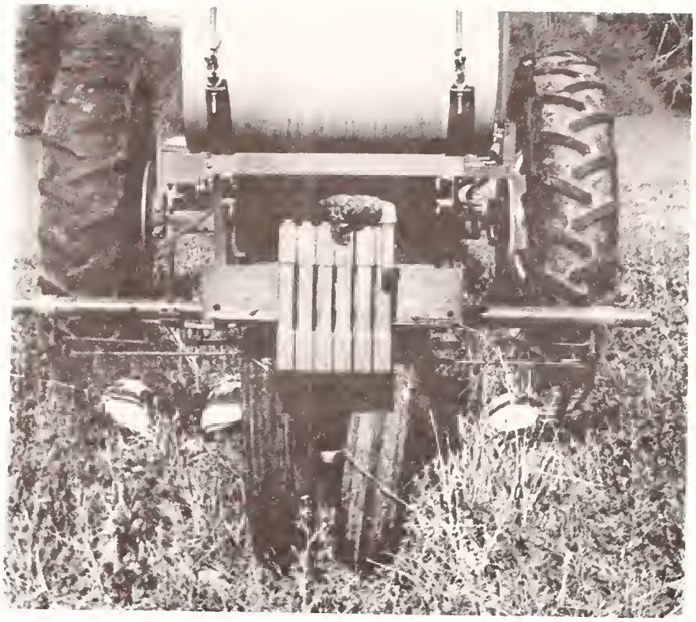

Figure 2. Stoneville Wiper applying herbicide in cottonwood reproduction nursery.

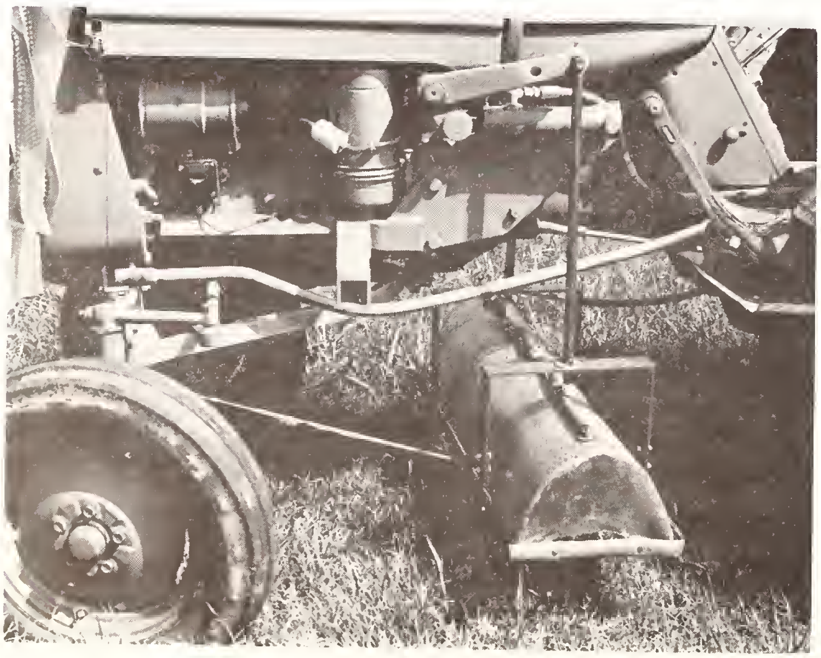

Figure 3. Hooded Sprayer mounted under front of tractor.

Figure 4. Hooded Sprayer applying herbicide between rows in a cottonwood plantation.

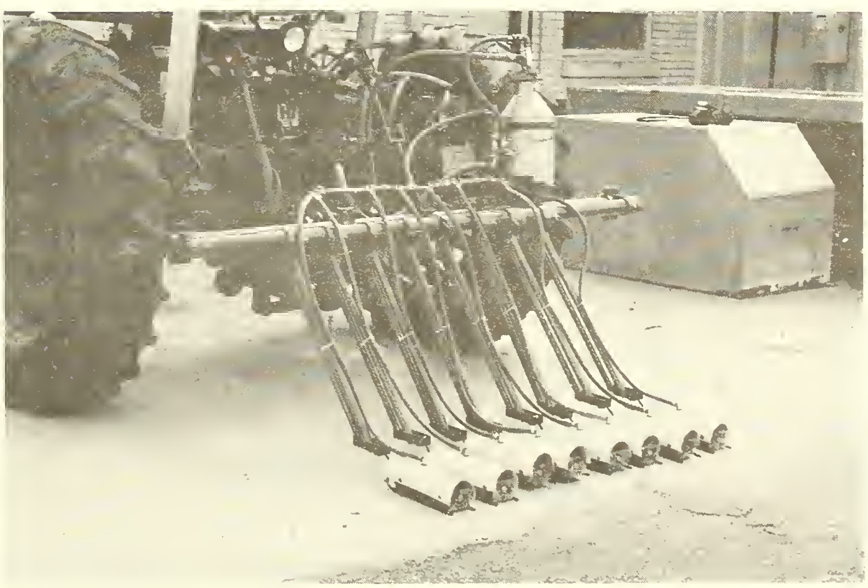

Figure 5. Two-in-One Applicator mounted on rear of tractor.

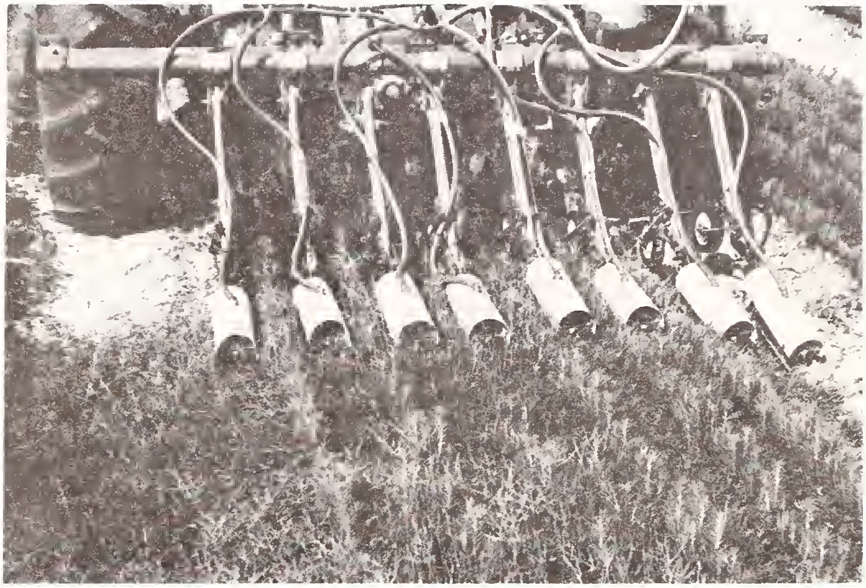

Figure 6. Two-in-One Applicator applying herbicide to bermudagrass in a pine seedling nursery bed.

LONGLEAF PINE PRODUCTION --- A COOPERATIVE ENDEAVOR

by

ALBERT G. KAIS[1]

The renewed interest in the growth of longleaf pine (*Pinus palustris* Mill.), necessitates close cooperation between the nursery and research to provide a longleaf pine desirable to the grower. The primary role of the nursery is to produce a high-grade, vigorous longleaf pine seedling that can survive and grow rapidly when outplanted in the field. Longleaf pine vigor influences survival, initiation of height growth, ability to compete with other vegetation, and ability to overcome effects of brown-spot needle blight. Factors affecting longleaf seedling quality in the nursery are seed source, seedbed density, nutrition, ectomycorrhizae, disease control, cultural practices, and practices for lifting and storing seedlings.

The current role of longleaf pine research is to develop genetical, mycorrhizal-cultural, and chemical technology to stimulate rapid height growth and to control brown-spot needle blight. Select seed sources from controlled pollinations are now being field-tested for disease resistance and fast growth capability. Longleaf pine inoculated with ectomycorrhizae while growing in the nursery bed had improved survival and increased growth when outplanted in the field. A benomyl fungicidal root dip treatment of nursery seedlings improved survival, controlled brown-spot needle blight, and stimulated rapid height growth.

Additional keywords: *Pinus palustris*, *Scirrhia acicola*, *Pisolithus tinctorius*, genetics, fungicides, brown-spot needle blight.

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LONGLEAF PINE PRODUCTION --- A COOPERATIVE ENDEAVOR

by

ALBERT G. KAIS

Longleaf pine, (*Pinus palustris* Mill.), once the most abundant of the southern pines, now occupies only about 25 percent of the area it once dominated (Mann 1969). Regeneration had been severely reduced by problems in nursery production and planting, possession of an inherent trait of delayed height growth, and severe damage caused by brown-spot needle blight (*Scirrhia acicola* (Dearn.) Siggers). Consequently, many longleaf pine sites have been planted to slash (*Pinus elliottii* Engelm. var. *elliottii*) and loblolly (*Pinus taeda* L.) pine. Recent nursery production figures for these three major southern pines reveal this trend (Abbot and Eliason 1968, Abbot and Fitch 1977).

	Seedling Production - M		
	1964 (36 Southern nurseries)	1974 (40 Southern nurseries)	Percent Increase (+) or Decrease (-)
Longleaf	7,461	6,818	-8.6
Slash	153,206	182,425	+19.1
Loblolly	199,050	337,191	+69.4

Recently, increased demands for wood and the many desirable characteristics of longleaf pine have stimulated a renewed interest in the growth of longleaf. Close cooperation between nurseries, State and Private Forestry, and research organizations is needed to provide the expertise and the technology to make longleaf pine a major component of the southern pine timber industry.

The Role of the Nursery

The primary responsibility of the nursery is to produce high-quality longleaf seedlings that can survive and grow quickly when outplanted in the field. The importance of this basic fact cannot be overemphasized. Quality of the nursery-grown seedling influences survival, initiation of height growth, the ability to compete with other vegetation, and the ability to outgrow or overcome the effects of brown-spot needle blight. Juvenile growth differences attributable to nursery influences can persist up to 10 years after outplanting (Snyder and Allen 1963). The major factors influencing longleaf pine seedling quality in the nursery are: 1) seed source, 2) seedbed density, 3) nutrition, 4) ectomycorrhizae, 5) disease control, 6) cultural practices and 7) lifting and storage practices.

Seed source.--Superior seed sources with rapid growth capability and disease resistance should be used. Reports concerning the inheritance of resistance in the F1 progeny of individual longleaf pine (Derr and Melder 1970) and the gain of desired characteristics by selection (Snyder and Derr 1972) indicate that superior seed sources will soon be available for nursery use.

Seedbed density.--Low seedbed densities reduce the number of culls before lifting (Scarbrough and Allen 1954) and promote improved survival and first-year growth of outplanted seedlings (Derr 1955). Seedbed planting at the rate of 15 seedlings per square foot is recommended (Mann 1969).

Nutrition.--The successful establishment and initiation of early height growth are directly correlated with root development and the early expression of vigor (Brown 1964). Lateral roots of longleaf pine are especially important for stimulating height growth (Derr 1948). So, a fertilization regime that favors the rapid production of extensive root systems on nursery seedlings is desirable. Slow release fertilizers, customized for root growth, could be a favorable fertilization alternative.

Ectomycorrhizae.--The use of a highly beneficial ectomycorrhizal fungi such as *Pisolithus tinctorius* (Pers.) Coker and Couch, can be extremely beneficial in tree nurseries and in artificial regeneration programs (Marx 1977). Ectomycorrhizae are not only beneficial for tree growth, but actually indispensable for survival and early growth of field plantations (Marx 1975). All nurseries contain some ectomycorrhizal fungi, but their frequency and type vary from nursery to nursery. Nurseries should promote the development of existing ectomycorrhizae or, if necessary, inoculate seedbeds with ectomycorrhizal fungi such as *P. tinctorius* to build up the ectomycorrhizal population. Marx found that the inoculation of longleaf seedbeds with *P. tinctorius* resulted in larger seedlings and fewer culls.[1/]

[1/]Marx, D. H. 1977, Personal communication, The effects of different rates of vegetative inoculum of *Pisolithus tinctorius* on ectomycorrhizal development and growth of longleaf and shortleaf pines. Abstract, Third North American Conference on Mycorrhizae, Aug. 23-25, 1977, Athens, Ga.

Treatment	Percent ectomycorrhizae		Fresh weight seedlings (gm)	Percent culls
	Pisolithus	Total		
Control	3	23	12.8	23
Pisolithus 100 cc/ft^2 (1/m^2)	19	34	16.7	14
Pisolithus 200 cc/ft^2 (1/m^2)	26	40	19.9	19

Disease control.--Control of brown-spot needle blight is crucial for the successful production of longleaf pine in the nursery. Nursery control is fairly simple with fungicidal sprays such as maneb, Bordeaux mixture, and chlorothalonil (Phelps et al. 1978, Kais 1975). However, nurserymen must also be aware of possible infection after needle clipping (Kais 1978). In any case, control with fungicidal sprays must be accompanied by meticulous practices of sanitation such as 1) removal of infected pine seedlings in the vicinity of the nursery, 2) removal and destruction of infected seedlings in nursery beds, 3) avoidance of using nonfumigated pine needles as mulch in beds, and 4) removal of clipped needle tissue from beds.

Cultural practices during growth.--Needle clipping and root pruning have been used to improve the quality of longleaf seedlings. Needle clipping performed two or three times during the growing season helps prevent seedling toppling, facilitates fungicidal applications, and expedites lifting and handling of stock. More importantly, it improves seedling survival (Allen 1955, Allen and Maki 1951, Shoulders 1967).

Pruning roots to 4 to 7 inches deep 6 to 18 weeks before lifting improves field survival of outplanted seedlings (Shoulders 1963). If done properly, this treatment increases root development, including lateral roots. This promotes a greater root absorption area for the uptake of water and nutrients and for ectomycorrhizal infection.

Lifting and packaging.--Careful handling and timing are necessary considerations during lifting, packing, and storage of longleaf pine seedlings. Destruction of seedling lateral roots during lifting drastically reduces the future growth capability of the seedlings (Derr 1948). Seedlings must be maintained under proper moist and cool conditions from the nursery bed to the storage room to prevent damage due to high temperature and dessication. Nurseries should move seedlings from the nursery bed to the field as soon as possible. Seedling quality degradation occurs with increasing time of storage.

The Role of Research

The future of longleaf pine depends on the integration of various management practices such as the use of disease resistant seed sources, production of high quality seedlings by the nursery, the application of field planting practices that stimulate rapid height growth, and the use of appropriate fungicides.

Current and future research plans at the Forest Science Laboratory at Gulfport, Mississippi, are directed toward developing genetical, mycorrhizal-cultural, and chemical technology to improve growth and to control brown spot. The program should produce 1) an improved selection system for longleaf pine, 2) brown spot resistant families of longleaf pine, 3) rapid, early height growth of longleaf pine, and 4) effective systemic fungicides for use against the disease. These goals are interrelated and require cooperation and coordination between scientists skilled in phytopathology, genetics, and silviculture.

Genetical.--This aspect of the research program may eventually provide higher quality longleaf pine seed sources for nursery production. Two important studies are now in progress. One test, designed to correlate laboratory and field screening for growth and brown-spot resistance of longleaf pine, could provide the technology for the rapid and accurate screening of quality seed sources. The other test, in which we have just completed 3 years of control pollinating, was designed to cross-pollinate progeny having disease resistance with progeny having rapid growth capability, disease resistance, or both. These select seed sources will be field tested during the next 4 years in order to determine the best breeding procedures and to provide higher quality individuals for advanced generation seed orchards.

Mycorrhizal-cultural.--This portion of the program may provide the technology to stimulate rapid height growth of seedlings. Ectomycorrhizae, herbicides, fertilizers, fungicides, containers, and their interactions are the major factors that will be studied for stimulating rapid height growth. Three-year results of an ectomycorrhizal-benomyl test indicated that seedlings inoculated with the ectomycorrhizal fungus P. tinctorius in nursery beds had better survival and growth than untreated seedlings.[2/]

Treatment levels/Pt	Survival %	Root collar diam. (cm)	Height (cm)
High Pt - 25%	84.6	2.71	19.6
Medium Pt - 15%	82.5	2.71	19.6
Low Pt - 5%	72.9	2.69	18.5
No Pt - 0%	63.9	2.39	13.1

Ectomycorrhizal treatment had no effect on brown-spot needle blight

Chemical.--This phase of the research program may provide the technology for control of brown-spot needle blight. It is designed to 1) identify effective, environmentally safe fungicides, 2) determine most effective and efficient fungicidal application methods, 3) determine effect of fungicides on growth, and 4) determine duration of control by fungicides.

[2/] Kais, A. G., G. A. Snow, and D. H. Marx. 1980. The effects of benomyl and Pisolithus tinctorius ectomycorrhizae on survival and growth of longleaf pine seedlings. Unpublished manuscript.

Three benomyl fungicide studies now in progress are of particular interest to nurserymen. In one study, a benomyl seedling root dip application has effectively controlled brown spot on longleaf pine during the first 3 years after outplanting.[3/]

Pt levels	1977		1978		1979	
	+Ben.	-Ben.	+Ben.	-Ben.	+Ben.	-Ben.
	Percent infection					
High Pt - 25%	4.8	22.4	29.9	54.4	41.2	58.7
Medium Pt - 15%	6.1	23.6	26.3	50.4	39.3	54.6
Low Pt - 5%	7.7	19.6	30.8	51.8	44.5	56.8
No Pt - 0%	4.7	21.7	29.2	53.5	46.6	62.6

Both survival and rapid height growth were stimulated by disease control.

In the second study, benomyl-treated seedlings were outplanted in five different states (LA, MS, AL, GA, and FL). Benomyl controlled brown spot at each location and also stimulated higher survival.

Treatment	LA	MS	AL	GA	FL
	Percent infection				
1% Benomyl	36.2	5.9	17.7	10.6	34.7
5% Benomyl	23.4	3.2	5.9	6.4	13.0
10% Benomyl	14.8	2.7	6.1	4.2	14.1
20% Benomyl	15.4	3.0	5.6	6.9	11.0
Clay control	64.1	11.9	30.7	26.5	61.3

[3/] Kais, A. G., G. A. Snow, and D. H. Marx. 1980. The effects of benomyl and *Pisolithus tinctorius* ectomycorrhizae on survival and growth of longleaf pine seedlings. Unpublished manuscript.

The third study is evaluating how benomyl affects survival of longleaf pine seedlings after different cold storage periods.

To date, benomyl shows great promise for brown-spot control. It has been most effective when used as a root dip treatment before outplanting of nursery run seedlings. The fungicide may be registered for root dip application in the near future. With registration, nurseries will be able to treat seedlings with benomyl before packing and shipping. This treatment would not only improve survival but also provide disease control during the critical infection period when the longleaf pine seedlings are in the grass stage.

The future of longleaf pine looks very promising. However a concerted effort by research, State and Private Forestry, extension, and each nurseryman is needed. By combining existing technology with new developments, the nurseryman will be able to provide the high quality product needed by forest managers.

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ETHYLENE ABSORBENT INCREASES STORABILITY OF LOBLOLLY PINE SEEDLINGS

James P. Barnett[1/]

Abstract.--Adding the ethylene absorbent, Purafil®ES, to bags of loblolly pine seedlings held in cold storage for 6 weeks improved root regeneration of seedlings over that of the control. Field survival was also increased after storage of 3 and 6 weeks with Purafil ES sachets. Treatments did not affect seedling height after one growing season.

Additional keywords: *Pinus taeda*, seedling survival, Purafil®ES, potassium permanganate.

Ethylene can damage many plants and fruits in storage (Abeles 1973). In amounts as low as a few hundred ppb, ethylene can reduce plant vigor, intensify aging of various plant parts, and reduce stock quality. Dormant nursery fruit stock is damaged if stored in an atmosphere containing ethylene (DeClement et al. 1979). Ripening fruit produces ethylene; other plant tissues also do so (Lieberman and Juniski 1971, Mapsom and Hulme 1970). Mechanical injury increases ethylene production (Kramer and Kozlowski 1979), so the lifting of nursery seedlings probably results in ethylene being produced in their roots. The sensitivity of plants to ethylene varies, and we have little information on how sensitive pine seedlings in storage might be to ethylene.

This study examined how including an ethylene absorbent in storage bags of loblolly pine seedlings affects root regeneration and field survival and growth.

METHODS

On January 4, 1979, I lifted loblolly pine seedlings, grown at the Columbia Nursery of the Louisiana Office of Forestry, and separated them to provide for three replications of treatment variables. Treatments consisted of 21 and 42 days of storage with and without ethylene absorbent. The absorbent is potassium permanganate absorbed on an aluminum (Purafil®ES[2/]) medium; it oxidizes ethylene to water and carbon dioxide (Abeles and Heggestad 1973). Purafil ES is packaged for several applications. In this study two small sachets (24 g each) were placed in polyethylene bags that contained about 50 seedlings. The sachets were stapled inside the bag so they would not contact water, which could reduce the effectiveness of ethylene absorption.

After 21 and 42 days of seedling storage at 34°-36°F, five seedlings per treatment replication were potted in sand and placed in a growth chamber for evaluation of root regeneration potential. The growth chamber was programmed for constant 75°F temperatures and 18 hour photoperiods of 1500 footcandles. After 4 weeks in the growth chamber, seedling roots were washed from the sand and numbers of new roots counted. The number of new roots per seedling was used as an estimate of root regeneration potential.

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2/ Mention of trade names is for information only and does not constitute endorsement by the USDA Forest Service.

Another 25 seedlings from each treatment replication were outplanted on a silt loam soil. Survival and heights were measured in the dormant season 1 year later.

The data were statistically analyzed in a completely randomized design. The 0.05 level was used to show significance in root regeneration potential. The 0.10 level was used for statistical tests of field measurements because I expected greater variation in the field data.

RESULTS AND DISCUSSION

Adding Purafil ES sachets to bags containing loblolly pine seedlings did not affect root regeneration potential after 3 weeks of storage. But after 6 weeks, seedlings with the ethylene absorbent produced significantly more new roots (Table 1). Bags with two sachets enclosed averaged 149 new roots after 1 month; bags without sachets averaged only 85 new roots

Table 1.--Root regeneration potential (RRP), survival, and heights of loblolly pine seedlings lifted from nursery beds and stored in polyethylene bags with and without ethylene absorbents a/

		Stored 3 weeks			Stored 6 weeks		
Treatment	Rep.	RRP	Survival	Height	RRP	Survival	Height
		No.	Percent	Feet	No.	Percent	Feet
Control	1	163	96	1.4	80	88	1.4
	2	133	76	1.2	90	88	1.3
	3	120	84	1.2	84	88	1.2
	Average	139a	85b	1.3a	85b	88b	1.3a
Purafil	1	125	96	1.2	158	92	1.4
	2	106	92	1.3	143	92	1.2
	3	159	88	1.3	147	96	1.2
	Average	130a	92a	1.3a	149a	93a	1.3a

a/ Means within columns followed by the same letter are not significantly different at the 0.05 level for RRP and at the 0.10 level for field measurements.

Seedling survival after one growing season was unaffected by length of storage, but Purafil ES in storage bags did improve survival by an average of 6 percentage points (Table 1). Seedling heights were not affected by either length or type of seedling storage.

Though no direct measurements of ethylene were made in this study, the improvement in seedling root regeneration and survival with the addition of an ethylene absorbent suggests that ethylene is produced in lifted pine seedlings. This ethylene production may be at least partly responsible for rapid deterioration of seedlings in storage.

RECOMMENDATIONS

The results from this preliminary study are positive enough to justify further study. Additional studies should better identify concentration-response relationships and the cost effectiveness of adding ethylene absorbents to sealed storage bags or to cold storage facilities if seedlings are stored in bales. These evaluations should be made in terms of improved survival and growth in the field.

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SEEDLING BED DENSITY INFLUENCES SEEDLING YIELD AND PERFORMANCE [1]

John G. Mexal

Abstract. The growing density in the seedbed impacts not only the yield, but also the grade and morphology of southern pines. The biological optimum appears to be a density of about $200/m^2$. This density optimizes the balance between individual seedling biomass and total biomass production. Morphological advantages at time of lifting which are attributable to density will result in long-term growth advantages expressed as increased individual tree volume.

Additional key words: *Pinus taeda*, *Pinus elliotii*, dry weight, grade, plantation performance.

The nurseryman is charged with the responsibility of optimizing and/or maximizing nursery production given certain economic constraints. Through his cultural practices ultimately he is responsible for successful seedling performance in the plantation. An important factor influencing nursery production as well as field performance is growing density. The relationship between growing density or plant population and crop yield is very strong regardless of the crop under study, and over the years, scientists have endeavored to define the optimum growing density. Studies with southern pines generally have focused on maximizing seedling numbers in the nursery. However, some studies have attempted to define the optimum population based on certain morphological standards, i.e. seedling grade or, in some cases, on the performance following outplanting. Regardless of the study objective, crop yield frequently is defined as the number of seedlings attaining a minimum size. Size is usually defined in terms of height and caliper, but also can be defined in terms of individual seedling biomass. An alternative method used by some is to define the population in terms of total biomass per unit area.

The objective of this paper is to address the impact of seedling density on crop yield and field performance. Yield, in this case, will be defined both as the number of seedlings attaining a minimum size or grade and as total biomass production. First, I will explore the interaction between density and yield in the conventional sense, i.e. seedling number, and second, the interaction of density and total biomass production. Then, I will examine the relationships between seedling density and field performance.

The relationship between density and yield is not simple. These two factors are influenced by other nursery practices such as fertility, irrigation, and seed quality. However, this paper will be limited primarily to the relationship between these two factors while holding other parameters fixed.

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SEEDLING GRADE

Many investigators have examined the relationship between density and seedling yield, but there is little agreement among those offering recommendations; recommended densities range from $215/m^2$ to $480/m^2$ (Table 1). Clearly, there is disagreement over optimum density, but probably because the authors may have used different definitions of a seedling acceptable for outplanting. Wakeley's original grading criteria are used frequently, in spite of the reported inadequacies of this grading scheme (Wakeley 1954).

Table 1. Recommended seedling bed densities (no./m^2) for Southern pines.

Reference	Seed Bed Density (no./m^2)	
	Loblolly	Slash
Burns and Brendemuehl, 1971	---	430-480
Foster, 1956	430	430
Muntz, 1944	---	320
Shipman, 1964	215 - 270	215 - 270
Shoulders, 1961	430	430
Range	215	265

The relationship between seedling density and grade is shown clearly in a study by Hansbrough (1957). As density increased from $320/m^2$ to $645/m^2$ the ratio among grades decreases from predominantly grade 1 seedlings to predominantly grade 2 seedlings; the proportion of grade 3 seedlings increases from 6% to 22%. A closer examination of these seedlings demonstrates the overall superiority of the higher grades. The dry weight of grade 1 seedlings averaged about 7.7 g regardless of density. However, grade 2 seedling dry weight averaged 2.7 g, while grade 3 averaged 1.2 g. Relative to grade 1 seedlings, these are reductions of 65% and 85%, respectively. Root weights were reduced proportionately more than shoot weight and the R/S ratios decreased from 0.26 to 0.22 and 0.22 for grades 1, 2 and 3, respectively. Based on biomass and R/S ratios, grade 2 seedlings resemble grade 3 more than grade 1. However, the seedings were not outplanted to determine potential performance differences.

BIOMASS PRODUCTION

The problems associated with visually assessing seedling grade are avoided by examining biomass production either on a individual seedling basis or on a unit area basis. This eliminates the need to categorize the trees based on arbitrary criteria, and allows examination of the entire population.

Both individual seedling biomass and total plot biomass have been used successfully to describe agronomic crop yields (Willey and Heath 1969). However, only the former has been used to date to characterize southern pine crops. Simple transformation of the data will convert one to the other. Possibly the best information to illustrate this point comes from a study by Harms and Langdon (1977) installed at the Westvaco nursery in Summerville, South Carolina. They reported that seedling dry weight decreased markedly as seedling bed density increased (Fig. 1). Concomitant with the biomass decrease was a shift in biomass partitioning. The ratio of root weight to shoot weight decreased about 25% over the densities tested. The shift toward a greater imbalance between root and shoot weight with increasing density conceivably could result in reduced field performance.

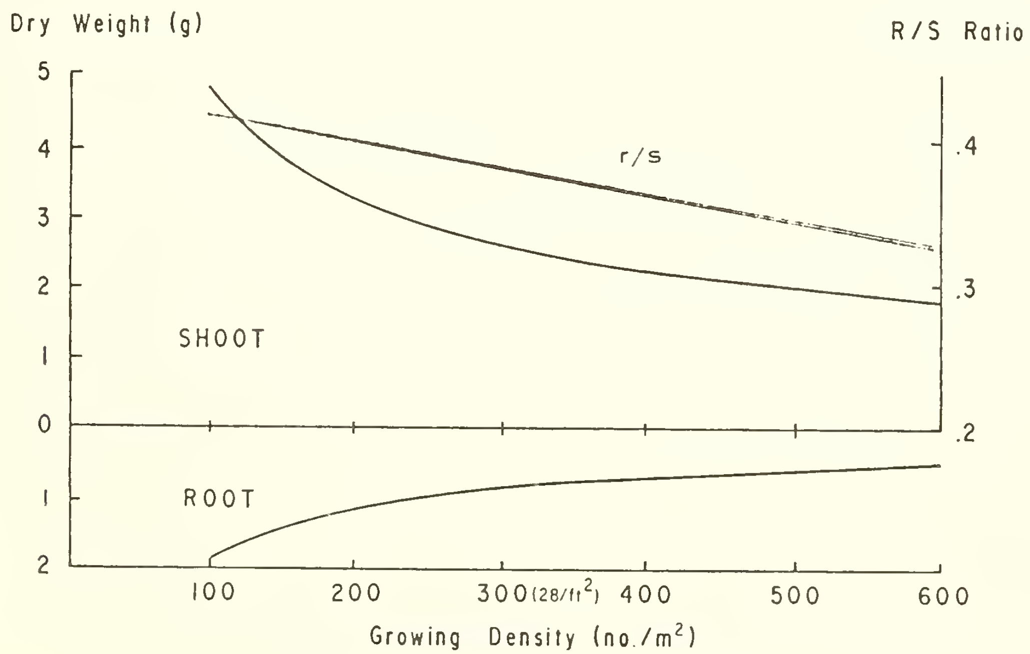

Figure 1.--The effect of growing density on root and shoot weight and root/shoot ratio of loblolly pine (Harms and Langdon 1977).

The question of "optimum" density cannot be resolved simply by examining Figure 1; unless it is known that a particular range of seedling dry weights or R/S ratios is preferable to another. I doubt that this information is available. An alternative approach is to transform the data and examine total yield per unit area as a function of density (Willey and Heath 1969). To accomplish this, the reciprocal of seedling density or growing area/plant is plotted against the reciprocal of biomass per unit area (Fig. 2). This relationship generally is linear and extrapolating to the intercept yields the theoretical maximum yield or "P" value (Willey and Heath 1969). In this study, the maximum amount of biomass that could be produced is 1.9 kg/m^2. This value appears to be consistent with other studies (Hansbrough 1957, Switzer and Nelson 1963).

Given the maximum yield of approximately 2 kg/m^2, the nurseryman must decide whether to concentrate that growth on a few large seedlings or spread it over many small seedlings. As nursery densities are lowered seedling size increases, but outplanting becomes more difficult. As densities increase, a larger proportion of the crop may be culled due to small size and field performance again may suffer due to an inability of small seedlings to get to compete with the weeds.

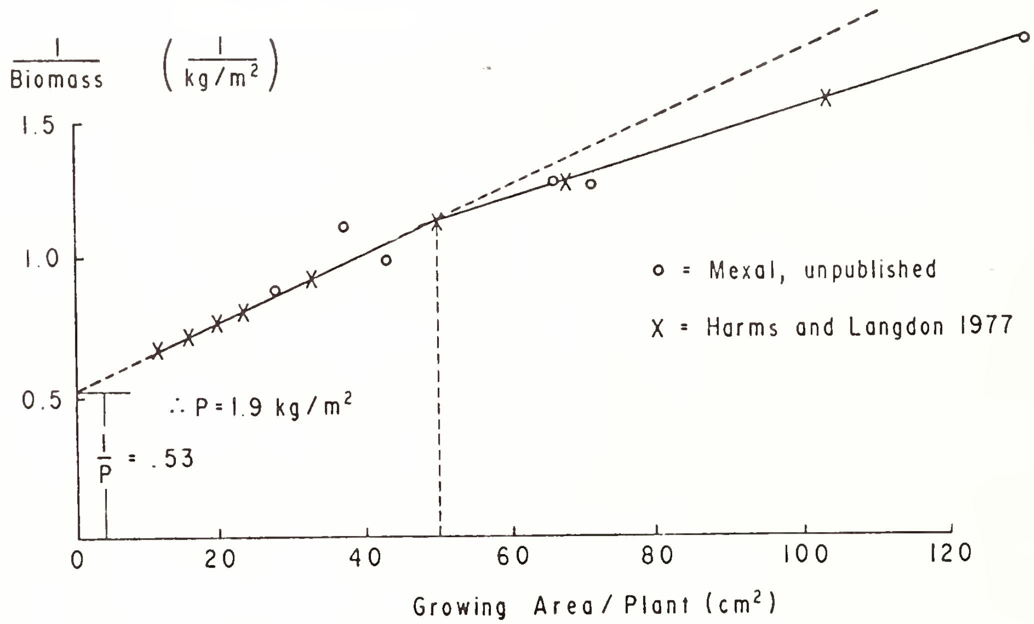

Figure 2.--Relationship between growing area and the reciprocal of total biomass production in loblolly pine.

The generally linear relationship between growing area and the inverse of biomass does not appear to hold for loblolly pine. The response is linear up to about 50 cm^2/plant; as the growing area increases beyond this point, the reciprocal of biomass diverges from the predicted line. The reasons for this are not entirely understood, but the relationship held in two studies of two nurseries (Harms and Langdon 1977, Mexal, unpublished results). A possible explanation for this divergence involves competition among plants. Below a growing area of 50 cm^2/plant, the seedlings are experiencing competition and the resultant biomass production per plant is linearly related to density. Competition is restricting growth and the site is underutilized on an individual seedling basis. Above 50 cm^2/plant, competition is not limiting and other factors limit growth. In this case the site is under-utilized on a unit area basis. This reasoning suggests that the biological optimum growing area for loblolly pine which maximizes both total biomass production as well as individual seedling biomass is about 50 cm^2/plant. This translates to a growing density of 200 plants/m^2 or 19 plants/ft^2.

There is an opportunity to shift total biomass production through the judicious use of fertilizers. Switzer and Nelson (1963) were able to increase pine seedling biomass production significantly by increasing fertilization rates. However, in their study, seedlings grown at a density near the biological optimum were much less responsive to changes in fertility levels than seedlings grown at higher densities. Apparently, seedlings grown at the biological optimum are less sensitive to the vagaries of nursery management practices.

FIELD PERFORMANCE

Describing the optimum growing density on a biological basis is intriguing. However, the decision to alter nursery management practices should be based on its ultimate effect on field performance; whether it be survival, height growth, or volume production. Few studies have addressed the subject of field performance of seedlings grown at various densities, and most of these studies have examined only short-term performance (Burns and Brendemuehl 1971, Shipman 1964). Many studies have emphasized seedling grading criteria in long-term performance evaluations, and most grading schemes are fraught with problems as Wakeley (1959) discovered. Therefore, it probably is unwise to assume that all grade 1 seedlings are equivalent regardless of growing density, cultural regime, etc. Likewise, the field performance of all grade 1 seedlings will not be equal even given identical field environments.

The data in the previous section suggests that seedling dry weight is very sensitive to growing density and may be a better, more reliable index of field performance than grade. Seedling dry weight is a reliable indicator of growing density and it also can be an index of future performance. Dry weight appears to integrate such factors as density, fertility, etc., into one common measure. Switzer and Nelson (1963) found seedling dry weight at time of lifting to be an excellent predictor of seedling height after three growing seasons in the plantation by the following equation:

$$\text{Ht (ft)} = 3.74 + 0.253\ (\text{D.W.}) \qquad r^2 = 0.79$$

This equation describes the relationship between dry weight and growth for three studies spanning three consecutive years. Autry (1972) reported the long-term effects from two of these studies, and found that individual tree volume was correlated with seedling dry weight at time of lifting (Fig. 3). It is evident that individual tree volume production is maximized by low nursery seedling density since the largest seedlings are produced at the lowest densities. The question now becomes what is the optimum growing density to maximize nursery bed utilization and yet realize maximum plantation performance? It would appear from the studies by Autry (1972) and Switzer and Nelson (1963) that future tree volume production in the plantation is inversely related to nursery density. The lower the density the greater the volume production. From studies by Harms and Langdon (1977) and Mexal (unpubl.) the biological optimum nursery density is known (see above). These two factors taken together point to a growing density of $200/m^2$. This density optimizes nursery production and also returns long-term growth benefits in terms of increased volume production.

Clearly, reduced bed densities offer many advantages. Culls should be practically eliminated and therefore the cost of removing them can be eliminated. Seed costs will also be reduced because of the elimination of cull seedlings. Growth regulation should improve as it is usually seedlings grown in dense beds which have a propensity to grow tall and spindly. This should result in savings in culture expenses. Seedling survival following outplanting is not likely to be impacted except where cull seedlings from dense beds are not removed prior to shipping (Burns and Brendemuehl 1971, Shipman 1964). Increased growth and volume production in the plantations are long-term gains to be realized. On the negative side, the nursery land base will have to be increased substantially and therefore growing costs will increase. Lifting and planting difficulties are likely to arise as seedlings from low density beds have larger, more fibrous root systems. All these factors will have to be considered collectively before the decision to alter growing density can be reached. Unfortunately, the question cannot be answered here, but will have to be answered based on each land manager's particular regeneration objectives, economic constraints, of course, experience. The objective of this paper was to present the biological side of the coin, and others will hopefully provide the economic side.

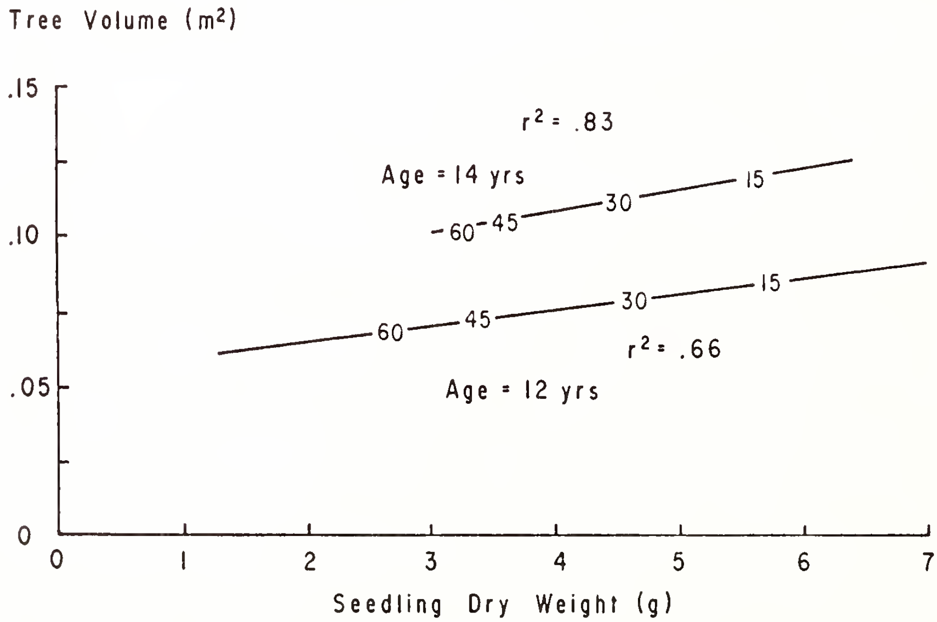

Figure 3.--Relationship between growing density, morphology, and volume yield in the plantation (Switzer and Nelson 1963, Autry 1972). The numbers in the figure refer to growing density (no./ft^2) yielding a particular mean dry weight

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THE STATUS AND PRACTICAL APPLICATION OF ECTOMYCORRHIZAE IN FOREST TREE NURSERIES AND FIELD FORESTATION

John P. Conn, Charles E. Cordell, and Donald H. Marx[1]

Abstract.--Artificial nursery seedbed and container mix inoculations with the ectomycorrhizal fungus Pisolithus tinctorius (P.t.) have demonstrated significant increases in nursery seedling growth and quality on a variety of conifer and some hardwood seedling species in the United States and Canada. Results obtained from related field outplantings have also shown significant increases in tree survival and growth on a wide variety of conifer species and planting sites. A practical machine application technique along with several additional ectomycorrhizal inoculum application methods utilizing commercial inoculum produced by Abbott Laboratories are presented for bareroot nurseries.

Additional keywords: Pisolithus tinctorius, commercial inoculum, conifer species, nursery seedling growth and quality, field outplantings survival and growth, ectomycorrhizal inoculum applicator-nursery seeder, bareroot nursery seedbed inoculation techniques.

NURSERY AND FIELD OUTPLANTING STUDIES

During the past several years, researchers at the Institute for Mycorrhizal Research and Development (IMRD), Athens, Ga., and pest management specialists, Atlanta, Ga., both with the USDA, Forest Service, have been conducting extensive mycorrhizal research and field application studies with a number of cooperating forestry agencies. The practical application of one ectomycorrhizal fungus, Pisolithus tinctorius (P.t.), in forest tree nurseries and field forestation has been the major area of emphasis for this work.

Since 1977, a national evaluation to test the effectiveness of different formulations of P.t. inoculum produced by Abbott Laboratories, Chicago, Ill., and the IMRD on a variety of conifer and some hardwood seedling species has been underway. A progress report on this evaluation was presented at both the

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western and eastern sessions of the Southern Nurserymen's Conferences in 1978 (Cordell, et al., 1978). During the past 3 years, over 80 bareroot nursery tests have been conducted in 38 states. Eighteen container nursery tests have also been conducted in nine states (including Hawaii) and Canada. In addition, over 20 field outplantings have been established in 13 states involving a variety of conifer species and forestation sites. The objectives of these tests have been to compare the performance of seedlings inoculated with *P.t.* with that of seedlings with naturally occurring ectomycorrhizae (i.e., *Thelephora terrestris*) and to compare the effectiveness of the Abbott inoculum with the inoculum produced by the IMRD.

Study Trends

Despite the early problems encountered with the Abbott *P.t.*, the majority of the nursery and field outplanting tests have been encouraging. Positive nursery benefits involving significant increases in seedling growth (fresh weights) and quality (cull reduction) have been obtained in most nurseries. Thus far, the *P.t.* inoculum produced by IMRD has been more consistent and effective than that produced by Abbott Laboratories. Preliminary results of the 1980 nursery tests, however, indicate that the quality of the Abbott inoculum has improved considerably, at least in certain batches.

In the outplanting tests, benefits from *P.t.* nursery inoculations have been consistently higher on poor quality planting sites. Results obtained from a 6-year-old outplanting study in Western North Carolina showed significant increases (25+%) in tree growth and survival on three pine species. The first outplantings of seedlings inoculated with Abbott *P.t.* were established in the spring of 1979. All outplantings are scheduled for a 10-year duration with annual measurements and progress reports.

ECTOMYCORRHIZAE INOCULUM APPLICATOR—NURSERY TREE SEEDER

Despite the experimentally proven benefits of *P.t.* to the nursery and field forestation, the operational use of *P.t.* in bareroot nursery seedlings production remains impractical. This is due, primarily, to projected seedbed inoculation costs. In an attempt to develop an effective and practical means of applying *P.t.* inoculum, a machine with the capability of simultaneous application of *P.t.* inoculum and nursery seedbed sowing was constructed by the U. S. Forest Service in 1979 (Figure 1).

The ectomycorrhizal inoculum applicator-nursery tree seeder was constructed through the modification of an Øyjard nursery seeder. By using this machine, a 2/3 (67%) reduction in ectomycorrhizal inoculum requirements can be realized as a result of the inoculum being applied in eight 2-inch width seedbed rows (bands) immediately followed by the seeding. Previous inoculation methods involved a broadcast inoculum application to the entire seedbed surface.

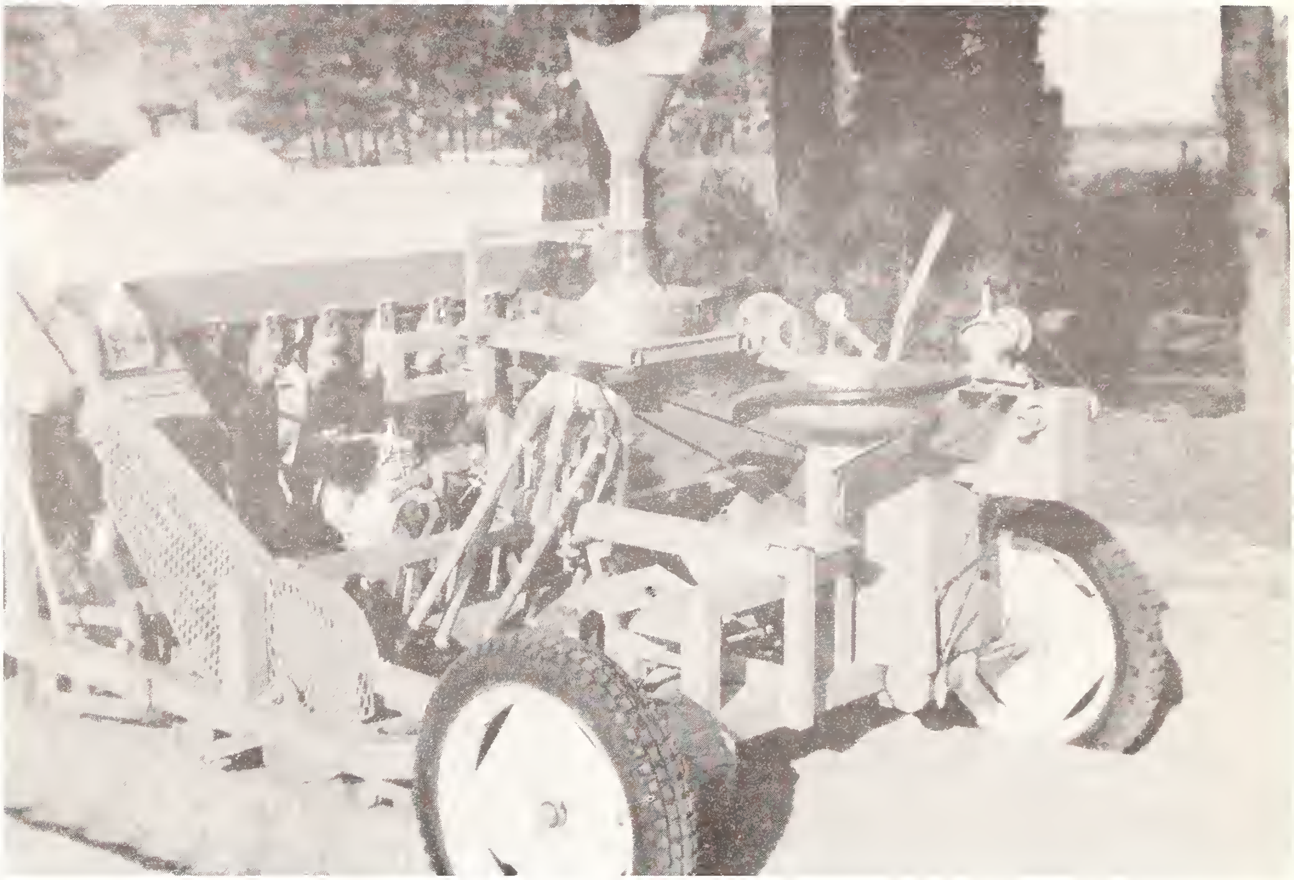

Figure 1.--Ectomycorrhizal inoculum applicator-nursery tree seeder.

The prototype ectomycorrhizal inoculum applicator-tree seeder has three separate methods of inoculum application. The inoculum can be injected at a desired soil depth, injected at a desired soil depth and plowed to mix the inoculum into the upper soil layers, and dropped on the seedbed surface and tilled in by means of a rototiller attachment.

In the spring of 1980, the effectiveness and practicality of the ectomycorrhizal inoculum applicator-nursery seeder were evaluated in four southern nurseries. The results of these nursery evaluations will be available in the spring of 1981. Field outplantings involving selected nursery treatments displaying effective P.t. ectomycorrhizal development are also planned.

ADDITIONAL ECTOMYCORRHIZAL INOCULUM APPLICATION TECHNIQUES

Other ectomycorrhizal inoculum application methods which may be considered for the practical and effective application of inoculum in bareroot nurseries are as follows:

1. Broadcasting the vegetative mycelium-vermiculite-peat inoculum on the seedbed surface with a conventional nursery fertilizer spreader and roto-tilling it into the soil with a bed shaper just before seeding. Although having a major advantage of simplicity in operating this method also has a major disadvantage of requiring large volumes of expensive inoculum.

2. Spores of ectomycorrhizal fungi such as _P.t._ may be used as inoculum either by mixing with the hydromulch and applying immediately following seeding or by encapsulating tree seed with a coating of spores. Nursery tests evaluating the relative effectiveness of the spore and mycelium inoculum techniques have shown the mycelium inoculum to be consistently more effective in promoting _P.t._ ectomycorrhizae than the spore inoculum. While offering primary advantages of simplicity and reduced cost, the spore inoculation methods require large volumes of spores with unknown viability and purity.

_P. t._ INOCULUM AVAILABILITY

Abbott Laboratories, Chicago, Ill., has developed techniques for the commercial production of _P.t._ mycelium-vermiculite-peat inoculum. However, the future commercial production of _P.t._ inoculum by Abbott, or any other producer, will depend primarily on consumer demand (forest tree nurseries) and prevailing economic conditions. The present indicated nursery demand for _P.t._ inoculum and current economic conditions are not favorable for the wholesale commercial production of this product. Any _P.t._ inoculum production by Abbott Laboratories in the near future will most likely be arranged through special agreements for custom _P.t._ inoculum orders between various nurseries and Abbott.

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Control of Fusiform Rust in Pine Tree Nurseries with Bayleton[1,2]

by

S. J. Rowan [1]

Abstract.--The systemic fungicide Bayleton provided excellent control of fusiform rust on southern pine seedlings in nursery and greenhouse plantings. As few as three foliar sprays per year provided control. A seed soak treatment needs to be supplemented with foliar sprays to provide control throughout the rust hazard season.

The systemic fungicide Bayleton (triadimefon) is effective against several plant diseases including rusts and mildews on a wide variety of hosts (Siebert, 1976). The chemical is registered in the United States for control of azalea petal blight and has 24-C registrations in several Southern States for control of fusiform rust in nurseries. Previous data (Mexal & Snow, 1978; Snow et al. 1979) indicated that foliar sprays and seed soak treatments of Bayleton would control fusiform rust on pine, but that spray frequency or dosage rate needed to be reduced to avoid phytotoxicity. In those tests five or more sprays of 8 ounces per acre was phytotoxic. The seed soak treatment also needed further testing to determine if it would provide control for the duration of the rust hazard season (from date of seed sowing until the first week of July).

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I have tested seed soaks and foliar sprays of Bayleton in nursery and greenhouse conditions. My purpose was to determine: (1) the minimum number of foliar sprays needed to control the disease and (2) the duration of control obtained from a seed soak treatment.

Methods

Study plots were established in the Georgia Forestry Commission's Davisboro Nursery. A study plot was 4 feet wide and 50 feet long, and the study was arranged in three randomized complete blocks. Improved loblolly pine seeds were sown at a rate calculated to produce 25 seedlings per square foot of bed space. Treatments included: (1) a check on which no fungicide was applied; (2) Bayleton seed soak (24 hours in an aqueous solution containing 600 mg active ingredient (a.i.)/liter after stratification and before a bird repellant was applied; and (3) Bayleton foliar spray (125 gallons/acre of 600 mg (a.i.)/liter) applied (A) twice (5/3 & 6/25), (B) three times (5/3, 5/29, 6/25), and (C) four times (5/3, 5/22, 6/7, 6/25). Final observations were made in December on a minimum of 400 seedlings from the center of each plot.

In the greenhouse, a mixed lot of open-pollinated slash pine seed was used. Seed were soaked 24 hours at room temperature in aqueous solutions containing 400, 800, or 1600 mg (a.i.)/liter of Bayleton prepared from a 50% wettable powder formulation. The seed were air dried after treatment, germinated in a 50:50 (v/v) mixture of sandy clay loam and vermiculite, and transplanted (20 seedlings of each treatment) to each of five replicate flats.

Foliar sprays were formulated to contain 400 mg of Bayleton (a.i.) and 2.5 ml of Agri-dex spreader sticker (Helena Chemical Company) per liter. Sprays were applied at 8 ml per flat (184 gallons per acre) of seedlings. The sprays were applied by passing the flats on a conveyor belt beneath a fixed atomization nozzle. Sprays were applied 7 and 14 days before as well as 7 and 14 days after inoculation with the fusiform rust fungus.

Seedlings in all treatments were inoculated with a suspension containing 75,000 basidiospores of *Cronartium quercuum* f. sp. *fusiforme* per ml 51 days after seedling emergence (64 days after seed were sown) as previously described (Matthews and Rowan 1972). Numbers of galled seedlings were recorded 11 months after inoculation.

Results and Discussion

Foliar sprays of 125 gallons per acre of 600 mg Bayleton per liter (equivalent to 1.25 pounds of 50% WP Bayleton per acre) effectively controlled fusiform rust in the Davisboro Nursery when three or more applications were made. Only 7.0 percent of the seedlings from the seed soak treatment became infected, whereas 48.8 percent of the unsprayed check seedlings were infected (Table 1).

In the greenhouse, seed soaks provided some degree of rust control even though inoculations were made 64 days after treatment (Table 2). Thus, seed soaks provide some rust control from date of planting (4/15) through mid June (6/19), but the degree of

control is not adequate. Seed soak treatments need be supplemented with foliar sprays to effectively control the disease. Foliar sprays will effectively control the disease when applied 14 days before and nearly 14 days after infections occur (Table 2). A study is in progress to determine the degree and duration of control obtained from a combination of seed soaks and foliar sprays.

Bayleton appears to be a most effective control for fusiform rust in pine. Phytotoxicity noted in earlier studies (Snow et al., 1979) was not found when three or four foliar sprays were applied. Thus, when dosage rates are reduced, phytotoxicity is not a problem and effective rust control is obtained.

Table 1. Efficacy of Bayleton for control of fusiform rust of loblolly pine in forest tree nursery seedbeds at the Davisboro, Georgia nursery.

Treatment	Galled Seedlings (%)
Check	48.8 a
Bayleton foliar spray; 125 gal/acre of 600 mg/liter	
(A) Applied twice 5/3 & 6/25	0.4 c
(B) Applied thrice 5/3, 5/29, 6/25	0.0 c
(C) Applied four times 5/3, 5/22, 6/7, 6/25	0.0 c
Bayleton seed soak - 24 hours - 600 mg/liter	7.0 b

Treatment means followed by a common letter are not significantly different (P = .05) according to Duncan's Multiple Range Test.

Table 2. Efficacy of Bayleton for control of fusiform rust of slash pine in greenhouse culture

Treatment	Dosage (a.i.) mg/liter	Application versus inoculation	Galled seedlings (%)
Check	0		63.1 a
Seed soak	400	64 days before	66.6 a
Seed soak	800	64 days before	33.3 b
Seed soak	1600	64 days before	38.3 b
Foliar spray	400	14 days before	0.0 c
Foliar spray	400	7 days before	0.0 c
Foliar spray	400	7 days after	0.0 c
Foliar spray	400	14 days after	1.3 c

Treatment means followed by a common letter are not significantly different (P = .05) according to Duncan's Multiple Range Test.

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NURSERY DISEASE WORKSHOP

Moderator - Charles E. Cordell[1/]

Topic Discussion Leaders - Bob Kucera[2/]
S. J. Rowan[3/]
S. W. Oak [4/]
J. T. English [5/]
E. L. Barnard[5/]
C. E. Affeltranger[6/]
G. M. Blakeslee [7/]
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T. H. Filer, Jr. [9/]

ABSTRACT

Abstract.--The largest variety and quantity of forest tree nursery seedling production presently occurs in the southern United States. The recent increased emphasis on nursery seedling production and field forestation in the South is accompanied by an expanded variety of nursery disease problems that demand the utmost in disease protection and control applications for these high-value forest products. A variety of conifer and hardwood nursery disease problems along with appropriate control recommendations are discussed in detail.

Additional keywords: Conifer diseases, hardwood diseases, root rots, stem diseases, foliage diseases, integrated pest management, systemic chemical controls.

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INTRODUCTION

There are presently over 65 state, industry, and federal forest tree nurseries in the southern United States with an annual production exceeding 1 billion seedlings. This represents over 35% of all the nurseries and over 75% of the annual tree seedling production in the U. S. Eight to ten new nurseries have been constructed during the past 2-3 years reflecting the accelerated emphasis and demand on seedling production and reforestation in the south. Southern nurseries produce a variety of conifers (15+ species) and hardwoods 12+ species). The nursery sites in this region also represent a wide variety of soil types and environments from the Southern Appalachian Mountains in western Virginia and North Carolina to the subtropics in southern Florida.

This wide variety of seedling species and nursery sites has also resulted in the development of an associated wide variety of seedling disease problems. In addition, corresponding accelerated nursery seedling production costs and high-value products have significantly increased the disease impact on both conifers and hardwoods during the past 5-10 years. Consequently, some of our most valuable forest resource values are represented in our southern nurseries, demanding the utmost in disease protection and intensive coordinated integrated control efforts.

A variety of nursery disease problems occuring on both conifer and hardwood seedlings along with appropriate control procedures will be discussed in the following sections. These discussions include some "old" disease problems such as charcoal or black root rot and fusiform rust on southern hard pines and several "new" diseases such as pitch canker and foliage blight on pines. The variety and magnitude of the diseases discussed reemphasize the apparent accelerating variety and impact of southern nursery disease problems.

BLACK ROOT ROT OF PINE

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Black Root Rot of pine seedlings is caused by the combined action of two fungi, *Fusarium oxysporum* and *Macrophomina phaseolina*. Above-ground symptoms are generally absent because nursery water and nutrients are available to the point that an affected seedling can grow very well with a severely-damaged root system. But the cortex of the root becomes reddened in small areas and then swollen and dark with a rough surface. This process usually begins at the lower end of the tap root and/or the laterals. A section in the middle of the root may become rough and swollen in a band. The disease progresses up the root to a node where new laterals often proliferate. There are no healthy laterals branching from the swollen parts of the root. Although mortality in the nursery was rare, it did occur in centers where the seedlings appeared to have died rapidly. The dead seedlings were dry with straw-colored needles.

Quantifying the Problem

It is advantageous to quantify the disease problem prior to lifting season in order to manage for intensity of culling, to determine if it will be profitable to lift beds with a high percentage of diseased seedlings, to determine if arrangements should be made to acquire replacement seedlings from alternative sources, and to determine if control measures will be necessary prior to the next planting. Another benefit is provided by having the data available to study for correlation with factors such as drainage, fertilization rates, herbicides used, proximity to risers, bed end or middle, etc., which may be contributing factors.

The survey used in the Alabama Forestry Commission was designed with help from State and Private Forestry. From previous data it was determined that 36 samples of 10 trees each should be taken in each pipeline at random spacing. The locations were determined by selecting 36 random numbers from the total number of feet in the pipeline. The number of healthy and number of diseased trees out of 10 was recorded at each

of the 36 locations. This data provides results with a relative error of $\pm$ 5% at the 68% confidence level. For example, in a pipeline 36 samples are taken at random intervals along the total of 3600 feet in the nine 400-foot rows. Each sample consists of 10 seedlings, yielding 360 seedlings in the 36 samples. If the sample shows an 8% incidence of disease, then the estimated amount of disease is 8% $\pm$ 5% with a 68% probability. In other words, the estimated amount of disease is between 3% and 13%; and this estimate will be correct 68% of the time.

The computer printout can give the mean disease incidence by Compartment, Pipeline, and Row. This value can be used to adjust inventories, culling practices, and determine where fumigation is needed.

Duncan's Multiple Range Test compares the incidence of disease in different rows of the pipeline. Significant differences are reported row by row in the pipeline to provide data to consider if proximity to the irrigation risers may be related to disease severity.

The same test is used to compare bed ends with the middles of the beds. This information is used to determine if there is a significant difference between them and provide a clue to control measures.

The Decision Process - Culling

Although the first procedure in managing a disease is identification of the cause, this was difficult in this case. Black Root Rot is described as having two associated fungi. Only one, *Fusarium oxysporum*, was consistently identified. High populations of nematodes were identified, but their locations did not correlate closely to areas of high disease incidence. There was also a suspicion that herbicides were a factor in the seedlings' poor root conditions. Upon consultation with the nurserymen, pathologists, and others involved, it was decided that the diseased seedlings should be culled because survival would be doubtful.

Cost of 10% Mortality (planting 778 trees/acre)		
Site prep at $90/acre x 10%	=	$ 9.00
778 trees at $13.50/1,000 x 10%	=	1.05
Planting at $35/acre x 10%	=	3.50
		$13.55

Cost of Culling from 10% to 0% (778 trees)

Grading efficiency at 50% level

(778 x 13.50/1,000 x 1/2)	= $5.25
78 trees/acre culled x .0135/tree	= 1.05
	$6.30

From this information the decision was made to cull diseased seedlings and take the loss at the AFC nurseries.

The Decision Process - Fumigation

At some level of disease protection, the benefits of fumigation will equal the costs. The variable factor in determining whether fumigation will be cost effective is the amount of disease it will prevent. In 1979 it was determined that a decrease of 1.8% of diseased seedlings would justify fumigation. Above this amount the benefits increase linearly assuming an effective fumigation. The results of the survey provide information that can save money in two ways: (1) to make sure beds are fumigated when the disease incidence is above this amount and (2) to avoid unnecessary fumigation at low disease levels.

Seedling Quality and Nursery Diseases

by

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Numerous pathogens can infect conifer and hardwood seedlings in southern nurseries; some attack roots and others aboveground parts. The quality of a seedling, as measured by its ability to survive and grow in the plantation, is dependent upon the interaction of numerous factors including nursery disease severity, physiological condition of the seedling, and the amount of stress imposed during the first year in the plantation. Nurserymen cannot control stress in plantations, but they can control diseases and the physiological condition of seedlings. Work is in progress to evaluate the effects of potassium fertilization in the nursery as well as of seedbed density on field performance of seedlings.

PHYTOPHTHORA ROOT ROT OF SAND PINE

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A recent root disease survey of sand pine identified a complex of pathogens causing substantial losses in sand pine plantations and natural stands in Florida. The pathogen most commonly associated with damaged plantations was *Phytophthora cinnamomi* (E. L. Barnard, Fla. Division of Forestry), a proven killer of sand pine.

Phytophthora root rot is a disease of the feeder roots. In nursery beds, the disease is distributed in pockets, often where soil drainage is incomplete. Top symptoms include stunting, chlorosis and browning of the foliage as the tree dies. Infected roots are usually darkened and the dead cortical tissues are easily stripped from the woody tissues beneath. Adventitious roots may sprout from just above the infected portion. If the infection progresses into the tap root, these woody tissues may become resin soaked. One Florida forest tree nursery has lost approximately 500,000 seedlings of the last two crops due to mortality and quarantine of infected seedlings (E. L. Barnard, Fla. Division of Forestry).

While the role of *Phytophthora cinnamomi* in sand pine root disease is not yet known, the high level of association of the fungus with damaged young plantings of sand pine is of concern to the nurseryman growing this species. Lightly infected nursery stock may appear symptomless from the top and these seedlings could be shipped to the field without detection. Under favorable conditions, incipient infections could intensify over several growing seasons and result in outplant and young plantation mortality.

Control in the nursery can be effected by not seeding sand pine in areas of the nursery where drainage is not adequate, fumigating nursery seedbeds and incorporating seedling crop inspection prior to shipping nursery stock to the field.

245 RHIZOCTONIA BLIGHT OF LONGLEAF PINE IN A FLORIDA TREE NURSERY

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Rhizoctonia blight of longleaf pine (*Pinus palustris*), caused by *Rhizoctonia solani*, is a current problem in some Florida tree nurseries. It is a potential problem throughout the Southeastern United States wherever longleaf pine is grown as a bareroot crop. Disease symptoms appear initially as chlorosis or water soaking of needle bases. Distal portions of needles appear healthy but gradually turn yellow and brown. With time needle bases darken and decay. Eventually infection progresses into the terminal bud and upper tap root. Death of the seedling usually follows. Within seedbeds, blighted seedlings occur in patches of variable size. These "infection centers" consist of dead seedlings surrounded by symptomatic seedlings varying in discoloration from yellow to brown.

Although *R. solani* has been associated with this disease for many years, pathogenicity was not verified until 1979 (Barnard and English, unpublished). Data concerning regional impact of this disease is lacking. However, one loss estimate has recently been completed. In one Florida nursery, severely blighted seedlings were rogued early in the growing season in an attempt to minimize spread within seedbeds. A systematic inventory of seedling canopy gaps resulting from this sanitation effort and additional disease related mortality revealed an overall loss of 8% (120,000 seedlings). Disease incidence was found to be positively correlated with period of seed storage prior to planting. The source of inoculum in the nursery is uncertain. To date, attempts to isolate the pathogen from two different seed lots (stored 10 and 0.5 years) have been unsuccessful.

CYLINDOCLADIUM SCOPARIUM: A PATHOGEN OF SEEDLING EUCALYPTUS

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Cylindrocladium scoparium Morgan, a widespread fungal pathogen on a variety of plant species including forest trees, has caused severe damage to container-grown eucalyptus crops in south Florida over the past two years. Losses in one nursery alone have reached nearly 220,000 seedlings, including 1/2 of one 1979 *Eucalyptus grandis* W. Hill ex Maiden crop. *C. scoparium* is endemic to much of the United States and, in Florida, is commonly recovered from leaf spots on *Eucalyptus* spp. in the field. Under nursery conditions including close spacing of seedlings, overhead irrigation, high relative humidity, and comparatively high temperatures, the fungus becomes a highly virulent and destructive pathogen on seedling eucalyptus.

Infections begin primarily as leaf spots, although stem lesions indicative of direct stem infections are sometimes present. With time, infections progress to a blighting of the lower foliage, accompanied by severe lesions or cankers on the lower stem. These stem lesions develop from a rather superficial browning of the outer cortical layers to a black and/or "constricted" canker, completely encircling the infected stem. Lesions are frequently centered at points of leaf petiole attachment, suggesting a progress of infection from leaves to stems through the petioles. Heavily infected seedlings often die in the nursery, but more frequently, severely damaged seedlings simply break off at the point of stem lesion development and are rendered unsuitable for outplanting.

Limited outplant trials have shown that seedlings with slight to moderate infections present no serious problem in terms of outplant performance. Survival and growth of such seedlings following outplanting does not differ appreciably from that of disease-free seedlings. Apparently, disease development is largely arrested once seedlings are removed from the nursery environment. Heavily infected seedlings, on the other hand, represent a very poor risk in terms of outplant success. Although a few of these seedlings will "come back" by means of root sprouts, etc., most fail altogether. Evidence suggests that root infections by *C. scoparium* are involved in these situations.

Results of a fungicide screening trial, conducted in south Florida in 1979, indicate that adequate control of this disease problem may be achieved in the nursery with applications of chlorothalonil and/or benomyl.

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[1]Reprinted from: BARNARD, E. L. 1980. Pest Management in Florida's Commercial Forest Nurseries. Fla. Sect. SAF. Spring Symposium. 11p. (in press).

PITCH CANKER IN FOREST TREE NURSERIES

George M. Blakeslee[1]

Pitch canker has been recognized for many years as a disease affecting numerous species of southern pines with the principle damage occurring as shoot dieback in intermediate-age and mature slash pine plantations. During recent years this canker-causing fungus has damaged younger slash pine plantations as well. In 1976-77, the pitch canker fungus, *Fusarium moniliforme* ~~var~~. *subglutinans* (FMS), was first reported causing severe shoot dieback symptoms in several southern pine seed orchards, and in 1978 it was determined that this same fungus was also damaging cones and seed of loblolly and slash pines.

In 1979, FMS was identified as the cause of late-season mortality in several southern pine nurseries in Florida. Observations made during the first half of the 1980 growing season have shown that FMS is also responsible for losses occurring early in the growing season. While the known distribution of the disease is presently restricted to nurseries in Florida, it is likely that the actual disease range encompasses a larger geographical area. To date, the seedling host range includes only slash and loblolly pines, with notable losses occurring only in slash pine, the species principally addressed in the remainder of this abstract.

Early in the growing season FMS can infect the lower stem at the groundline (root-collar), the upper portion of the tap root, the cotyledons, or the upper stem above the cotyledonary node. These infections result in a variety of symptom types including foliage discoloration and death of erect seedlings, foliage discoloration and seedling collapse (similar to classic damping-off symptoms), stem cankers, and top dieback. Throughout the remainder of the season, on seedlings with succulent tissues, wilt of the foliage and upper stem occurs following the development of lower stem, root-collar, or tap root infections. Seedlings with less succulent tissues gradually discolor and die. Later in the season as seedlings become larger, discrete, resin-soaked cankers can be detected principally occurring at the groundline or on the upper tap root. Occasionally, resin is exuded through the bark and into the soil in the area of the infected tissues.

The disease occurs as single- and multiple-tree infection centers scattered throughout the nursery. Seedlings of several different symptom types and stages can be found within infection centers that occasionally can encompass several dozen seedlings. The pathogen sporulates on diseased seedlings and this inoculum may be responsible for disease spread and intensification within the nursery. FMS also occurs abundantly in the soil near diseased seedlings.

In 1979, a single-point, late-season assessment of pitch canker-caused mortality was conducted in six nurseries in Florida. Seedling mortality

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(by seed source) ranged from 0 to ~9 seedlings per thousand (S/M). Within individual nurseries, the mean mortality level (per seed bed) ranged from .2 to 3.1 S/M with an overall mean of .9 S/M. These estimates of pitch canker-related loss are conservative in that they do not reflect losses that occurred earlier in the growing season nor do they include infected seedlings that had not expressed foliar symptoms at the time of assessment. While the within-nursery losses experienced to date have generally been low, the destructive potential of this disease may be better illustrated by the 15-25% mortality that has occurred in certain seed sources during the first half of the 1980 growing season.

Further losses may result from the outplanting of seedlings with incipient infections or from the inadvertent inoculation of healthy seedlings during the lifting, handling and outplanting procedures. Studies underway at the present time indicate that pitch canker-related mortality can account for a substantial proportion of the post-plant mortality of properly planted seedlings.

Control practices are not available at the present time, however substantial research is now underway to identify the source(s) of the pathogen, to determine the epidemiology of the disease, to better assess pitch canker-related losses, and to develop effective preventative and/or theraputic controls.

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SOUTHERN PINE TIP BLIGHT IN FOREST NURSERIES [1-4].

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1-4 A tip blight and subsequent dieback of loblolly and slash pines have been observed for the past three growing seasons in our southern nurseries. Nurserymen in Florida, Georgia, Texas, Arkansas, Alabama, Mississippi, and South Carolina have reported the problem. Outplanting of infected seedlings revealed good survival (91 percent) after six months.

Symptoms begin as a reddening of the tips of needles near the terminal bud. As the disease develops, the terminal bud is killed and a purplish constriction forms on the dead tissue. In advanced stages, only two to three inches of the terminal dies. Often a seedling will extend the terminal again and thus overcome the infection. Initial needle reddening occurs in late July or early August. Tests to determine the causal agent(s) by the Southeastern Forest Experiment Station have implicated a *Diplodia* sp., a fungus which has caused a dieback of nursery seedlings in the Lake States and Great Plains. 1-3 Two additional fungi, *Sphaeropsis* and *Phomopsis*, have also been associated with the problem, but these fungi may either be weak pathogens or foliage saprophytes.

Tip blight can be suppressed following initial symptom expression by applying the fungicides Bravo 50F or Bravo 75WP (2 1/2 lbs./100 gals. water at bi-weekly intervals in August and September. Another fungicide, Benlate, can also be used (8 ozs/100 gals. water on the same spray schedule. A cost-benefit analysis conducted at the Ashe Federal Nursery in Mississippi indicated that foliage fungicidal spray costs equalled protected seedling benefits when seedling infection was .6% and Benlate was used. However, the relatively low level of tip blight observed in most nurseries to date along with the high survival rate of outplanted diseased seedlings nullifies any apparent present necessity for control recommendations such as systematic fungicidal sprays and/or diseased seedling culling practices.

245 PRESENT STATUS, AVAILABILITY, AND REGISTRATION
OF BAYLETON ON
CONTROL OF FUSIFORM RUST [1, 2]

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During the last five years several systemic fungicides have been tested for efficacy against Cronartium quercuum ~~F. sp~~. fusiforme. Of these fungicides, the Mobay product Bayleton[R] has been the most effective in controlling fusiform rust. Being systemic, this fungicide has both therapeutic and protectant properties, thus the number of applications necessary to control fusiform rust is significantly fewer than was required for the contact fungicide ferbam. Results from field and greenhouse tests indicate that rust can be controlled in forest nurseries with three or four applications of Bayleton at a rate of six or eight ounces active ingredient per acre per application. The first spray should be applied 7-14 days after planting (when approximately 50% of the seedlings have emerged). The last spray should be applied during the third week of June, and the intermediate sprays should be equally spaced between the first and last sprays. Sufficient volume (75-100 gal per acre) should be used to insure complete coverage. In addition, the tank mix should contain six ounces of Agri-dex[R] surfactant-oil blend per acre volume of spray.

Availability. The distribution point for Bayleton in the southeast is:

Woolfolk Chemical Works, Inc.
P. O. Box 938
Fort Valley, Georgia 31030

Agri-dex can be obtained from:

Helena Chemical Co.
Suite 3200
5100 Poplar
Memphis, Tennessee 38137

Registration: As of September 1980, 24 C, registrations allowing use of Bayleton on pine seedlings for control of fusiform rust had been approved in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, and South Carolina. Each user of Bayleton must have in his possession a copy of the 24 C registration for his state at the time of application.

HARDWOOD DISEASES [1,2].

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Damping-off and root-rot continue to cause the most losses of young hardwood seedlings. We know how to control these losses but we gamble by not taking preventative methods. The most effective control is to use soil fumigation or solar soil sterilization.

Recent research data indicates that solar energy can be harnessed to sterilize soils and reduce root-rot diseases, nematodes and damping-off organisms. This simple technique requires the use of black plastic placed over soil and sealed to keep heat trapped in soil.

Chemical fumigants such as methyl bromide or methyl bromide-chloropicrin mixtures will give good results if applied properly. However, some soil moisture and temperature above 55°F is necessary to do a good job.

Graminae cover crops such as maize, sudex, and corn will help increase the endo-mycorrhizal population of fumigated nursery beds. These crops will increase endo-mycorrhizae on sweetgum, sycamore, ash, dogwood, redbud, cherry, yellow-poplar, and black walnut. For hardwood nursery beds we should consider soil fumigation as a tool to reduce the population of harmful fungi and not for weed control. Herbicides should be used for controlling weeds.

Cylindrocladium root-rot fungi can cause serious root diseases on yellow poplar, black walnut, cherrybark oak, black cherry, dogwood, redbud, and sweetgum. The only control consists of rotation of hardwood seedling crops and soil fumigation. The methyl bromide fumigant formulation MC-33 (methyl bromide - 67%, chloropicrin - 33%) remains as the most effective control for soil borne diseases such as cylindrocladium root rot.

Other root problems occur under certain conditions such as Fusarium root rot of sycamore and other hardwoods; Rhizoctonia root rot on several hardwood species; Pythium root rot of black locust and other hardwoods; and nematodes on several hardwood including black cherry. These root rot disease problems can all be controlled by effective soil fumigation.

Hardwood foliage diseases can be serious disease problems if defoliation occurs. Anthracnose of yellow-poplar and <u>Marssonina</u> leaf spot of black walnut are good examples of foliage diseases that may cause mortality.

When defoliation occurs, a protective fungicide must be used to protect the remaining foliage. Young seedlings, in particular, will die if the foliage is killed. The limited amount of root reserves in these young seedlings will prevent refoliation. For additional disease control, plow under all infected plant material to minimize disease spread to next year's crop.

NURSERYMEN MUST LEAVE HERBICIDE CHECK PLOTS

David B. South

Abstract--To determine if seedling injury is herbicide related, untreated check plots must be used throughout forest nurseries. Not using check plots in the past has resulted in failure to detect herbicide injury as well as falsely blaming herbicides for seedling injury. Approximately 50 feet of bed should be left untreated for every 4 acres.

There are two reasons why herbicide check plots must be used in forest nurseries. First, checks are essential for detecting herbicide injury that would otherwise go unnoticed. For example, at one nursery trifluralin was used as a preplant soil incorporated treatment for ten years. Several pine species including trifluralin sensitive shortleaf were grown on the treated soil. Seedling production of shortleaf was consistently poor, but because no check plots were used and because production of the other pine species was satisfactory, trifluralin injury on shortleaf remained unnoticed. At another nursery, napropamide was used operationally on soil with less than 1 percent organic matter. Root injury was observed for two years but was not attributed to napropamide. Use of check plots at these nurseries would have resulted in early detection of herbicide injury and would have prevented further seedling injury.

The second reason for using herbicide check plots is to avoid falsely blaming herbicides for seedling injury and to be able to more adequately determine the actual problem. Although many factors can cause seedling injury, herbicides are usually the first factor blamed for seedling injury. Fertilizers, insects, diseases, wind, nutrient deficiences, nematodes, and abnormal weather conditions can also cause stunting or injury. Numerous examples can be cited. At one nursery, seedlings were dying in patches in one compartment and herbicides were immediately suspected. However, the real reason for the injury turned out to be an improper ammonium nitrate application. At another nursery, seedlings were stunted and chlorotic. Chemical burn was thought to be the problem even though adjacent green trees had also been sprayed with the same herbicides. As it turned out, low soil pH was the true cause. At another nursery a wet, cool spring resulted in smaller than normal seedlings. However, herbicide injury was suspected by the nurseryman's superior. The nurseryman felt the cause of the small seedlings was weather related but had no proof due to having no check plots.

Check plots have been very useful in the past. For example, at one nursery numerous seedlings were broken over due to a brown lesion on the stem. Herbicides were not suspected in this case since the same injury occurred on untreated check plots.

The check plots should be spaced periodically throughout the nursery. A 50 foot length of bed should be left untreated for every 4 acres. The untreated area should be placed in the middle of the treated section and should be flagged. Signs stating "No Herbicides" would help prevent the area from being accidently sprayed. These areas will require frequent handweeding to prevent stunting due to weed competition.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

PRECAUTIONARY PESTICIDE USE STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of the reach of children and animals--away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays of dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Department of Agriculture, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.